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SECTION OF GEOLOGICAL SCIENCES

ANISOTROPIC SEDIMENTARY PARAMETERS*

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Introduction

The motivation for the experimental work analyzed and discussed in this paper was a simple one. It was a response to the following questions: (1) would estimates of textural parameters of a sample of sedimentary rock, from which different thin sections were prepared, differ significantly from thin section to thin section? (2) Would estimates of these parameters differ significantly among different directions within these different thin sections?

Experimental Design and Sampling

To answer the above questions, a sample of Pottsville sandstone,† Pennsylvanian, of Pennsylvania, was selected, and three mutually perpendicular thin sections were cut from the sample. Two sections were cut orthogonal to each other and to the bedding, and the third, orthogonal to the first two, was cut parallel to the bedding (FIGURE 1).

The 3 orthogonal thin sections were designated XY, XZ, and YZ. The Y axis is the strike direction of the sample, that is, N65°E, whereas the XY plane parallels the bedding plane. On each of the 3 planes, measurements were made in 6 different directions with respect to a reference axis in each plane. These directions were 0° (parallel to the reference axis), 30°, 60°, 90° (perpendicular to the reference axis), 120°, and 150°. The different planes, their reference axes, and the angles defining the different traverse directions within planes are indicated in FIGURE 2.

The parameters selected for this work were size, orientation, and packing. Measurement of the parameters, size, and packing were made for each of the 6 directions within each of the 3 faces; 5 traverses, or replications, were made at random for each direction within each face. Orientation measurements were made for each of the 3 faces.

Measurement Techniques

The techniques employed for estimating the parameters, size, orientation, and packing are as follows:

*This paper, illustrated with slides, was presented at a meeting of the Section on February 2, 1959.

†The sample was obtained from the personal collection of Joseph Hutta, Division of Geochemistry, Pennsylvania State University, University Park, Pa. The sample was collected 1 mile north of Tamaqua, Pa., on the Hazelton-Tamaqua Highway. The strike and dip of the specimen was N65°E, 40½°SE. The axis of the fold had a trend of N66°E.

Size. A method of measuring the size of a sediment is by means of grain intercepts (Chayes, 1950). If g_{ij} represents the ith grain intercept in the jth traverse of n_j grains, then the average intercept size of the traverse is

$$\frac{\sum_{i=1}^{n_j} g_{ij}}{n_j}$$

Quartz grains alone were measured for size.

Orientation. The estimate of orientation is defined as the angle between the reference axis and the longest long axis that could be measured on a grain; in this case, quartz.

Packing. Packing has been defined as the mutual spatial relationships among textural elements of a sediment (Kahn, 1956a), and is estimated in this experiment by Packing Density (P_d).

P_d, the measure of the amount of space in a sediment occupied by all grains is expressed as

$$P_d = 100 \frac{\sum_{i=1}^{n_j} g_{ij}}{t_j}$$

where t_j is the length of the jth traverse.

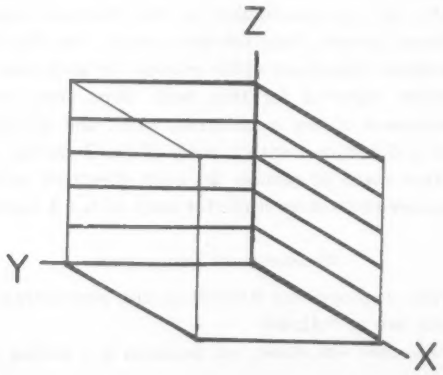

FIGURE 1. Schematic representation of cube of Pottsville sandstone showing bedding plane (XY) and planes perpendicular to bedding (XZ and YZ). The Y axis is the strike of the sediment.

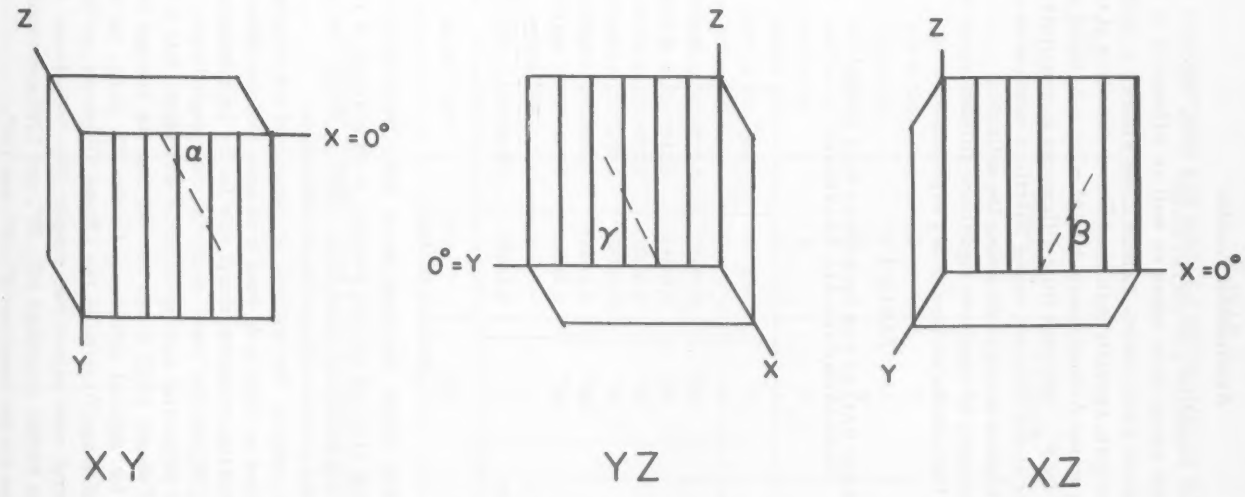

FIGURE 2. Graphic representation of the planes from which three mutually orthogonal thin sections were prepared. XY – the X axis is the reference axis, α is measured clockwise. YZ – the Y axis is the reference axis, γ is measured counterclockwise. YZ – the X axis is the reference axis, β is measured counterclockwise.

Experimental Results

TABLE 1, which summarizes the intercept size data, indicates differences in magnitude among slide means as well as differences in magnitude among directions within slides. TABLE 2 and FIGURE 3, summarizing the orientation data, certainly indicate different directions of concentrations of quartz grains. A close examination of TABLE 3, which summarizes the results for P_d, indicates little differences in magnitude among average values for slides. However, among directions within slides, there certainly are differences in magnitude among the estimates.

Are these differences in magnitude significant differences, or do they merely represent fluctuations inherent in any experiment?

TABLE 1

AVERAGE VALUES FOR INTERCEPT SIZE IN MM., AVERAGED OVER ALL TRAVERSES

Plane		XY	XZ	YZ
Direction	0°	0.1281	0.1228	0.1173
	30°	0.1284	0.1169	0.1175
	60°	0.1382	0.1004	0.1061
	90°	0.1216	0.0927	0.0976
	120°	0.1390	0.1004	0.0962
	150°	0.1264	0.1241	0.1125
Slide averages		0.1303	0.1095	0.1078

Analysis of Data

The experimental design described above leads immediately, for the variables intercept size and packing density, to an analysis of variance design called completely randomized (Hald, 1955), a design that permits us to determine the presence of significant differences.

Intercept size analysis. The analysis of variance of the intercept size data is summarized in TABLE 4. Here it is seen that the difference in magnitude between the average intercept size for the section cut parallel to the bedding (XY) and the thin sections cut perpendicular to the bedding (XZ and YZ) is real and significant. Furthermore, with the aid of the allowance (Federer, 1955) it can be seen that the average intercept size estimates for different directions, for the XY plane, the bedding plane, do not differ significantly. In the XZ and YZ planes, on the other hand, the intercept size values fall roughly into two groups. In both cases the values for the directions 60°, 90°, and 120° are significantly smaller than those for the directions 0°, 30°, and 150°.

TABLE 2

ABSOLUTE FREQUENCY DISTRIBUTION OF QUARTZ ORIENTATION FOR SLIDES

Slide	XY	YZ	XZ
Class (in degrees)	Frequency	Frequency	Frequency
90 to 100	15	8	2
100 to 110	8	4	5
110 to 120	13	7	7
120 to 130	15	11	5
130 to 140	12	7	17
140 to 150	5	7	10
150 to 160	9	9	16
160 to 170	7	14	19
170 to 180	4	13	19
180 to 190	13	12	13
190 to 200	7	16	13
200 to 210	11	5	13
210 to 220	5	7	14
220 to 230	11	7	5
230 to 240	11	8	3
240 to 250	11	4	2
250 to 260	13	4	4
260 to 270	4	5	3
Sample size	174	148	170

TABLE 3

AVERAGE VALUES FOR PACKING DENSITY AVERAGED OVER ALL TRAVERSES (IN PER CENT)

Plane		XY	XZ	YZ
Direction	0°	61.86	59.24	62.40
	30°	61.86	64.52	57.92
	60°	60.01	65.66	63.87
	90°	62.42	58.42	54.34
	120°	62.76	59.17	64.40
	150°	57.85	49.99	55.66
Slide averages		61.13	59.50	59.77

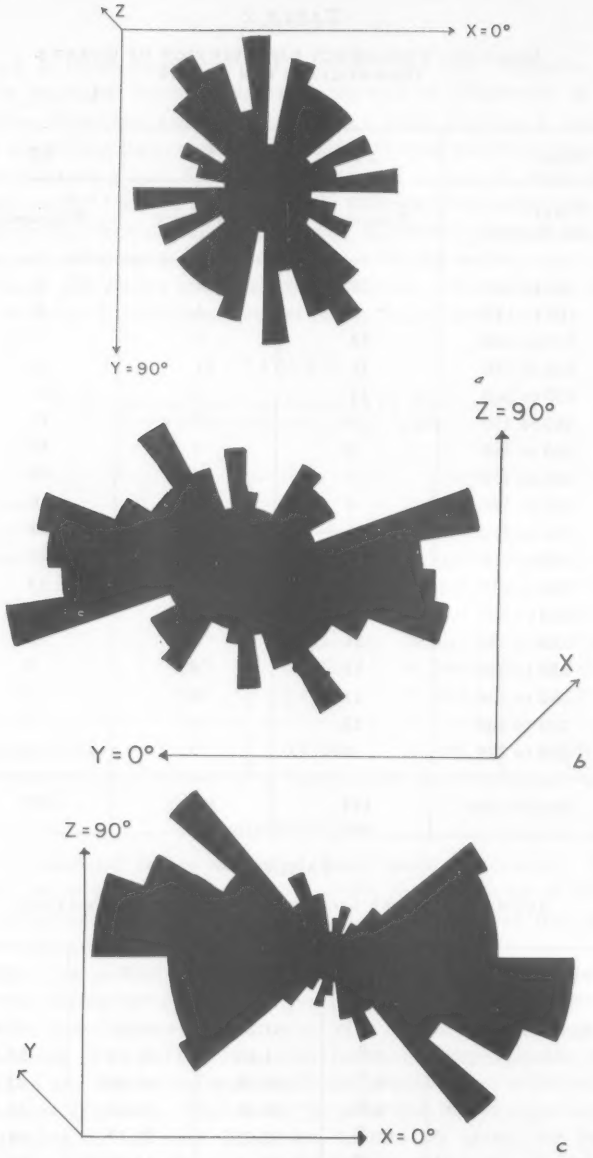

FIGURE 3. Graphic representation of the distribution of orientation measurements plotted on polar co-ordinate paper. Distribution of orientation measurements in: (*a*) bedding plane (XY), sample size = 174. (*b*) plane perpendicular to bedding, containing strike (YZ), sample size = 148. (*c*) Plane perpendicular to bedding and strike (XZ), sample size = 170.

The anisotropic character of the parameter size, as estimated by intercept size, is thus clearly evident in this analysis. Not only are the estimates of size significantly and consistently larger in the bedding plane, but within sections perpendicular to bedding there are significant differences in size. We thus face the question: Why are these differences present? The answer to this question involves not only the textural property under question, but also the processes under which sediments are formed and to which they react, the concept of a geological population, and the measurement technique utilized, as well as the interrelationship among textural parameters.

TABLE 4

ANALYSIS OF VARIANCE OF INTERCEPT SIZE IN MM.

Source of variation	Degrees of freedom	Sum of squares*	Mean square*	F.
Faces	2	93.7990	46.8995	8.91†
Directions within faces	15	78.9764	5.2651	6.26‡
Traverses within directions and faces	72	60.5686	0.8412	
Total	89	233.3440		

Allowance for directions = 0.0171 mm.

*Coded sum of squares and mean square.
†Significant at the 0.01 level.
‡Significant at the 0.001 level.

The basic unit of sedimentation has been defined as the thickness that has been formed under essentially constant physical conditions (Pettijohn, 1957). Thus we have a unit that approximates a population, for this is certainly a group consisting of individuals with common characteristics. The homogeneity of depositional conditions exists for all grains within the unit; the planes parallel to the bedding plane contain a whole unit or portions of such a unit. By virtue of this, the population generated by examining cross sections of sedimentation units is a population that contains portions of other populations. Since the planes parallel to the bedding plane and those perpendicular may be defined as different populations a priori, provided one knows he has sliced through more than one sedimentation unit, the question is: Do *these* populations

differ? The answer to this is obtained by examining the estimates of the population constants, the parameters.

Hence the intercept size differences among thin sections exist in part due to the assumption that one population was under consideration and not two. The further explanation of these differences lies in the technique of measuring grain size and the interrelationship between the technique and the parameter orientation.

Orientation analysis. The interrelationship between intercept size and orientation or, for that matter, the interrelationship between and among any two or more sedimentary parameters is not surprising. Griffiths described this (1952). The striking relationship in this case is worth noting and is discussed below.

The orientation data in TABLE 2 are graphically represented in FIGURES 3*a*, *b*, and c. A comparison of the observed distribution of orientation values in the bedding plane (XY) with a uniform distribution (Hald, 1952) reveals no preferred tendency for the long axes of the quartz grains to point in any one general direction. The distribution is essentially uniform and the isotropic nature of the variable is exhibited. On the other hand, in planes perpendicular to the bedding (XZ and YZ) a visual examination of the orientation data suggests a tendency for the long axes to cluster about a median value; however, when a comparison of expected and observed frequencies is made, this is confirmed only in the XZ plane. With respect to the YZ plane, the tendency is essentially centered about the trace of the bedding. In the XZ plane the concentration is a few degrees below the bedding trace, indicating an imbricating tendency with respect to the horizontal bedding plane.

Thus, on the basis of orientation analysis, one can predict the relative intercept size values. From an examination of the plane XY and the isotropic nature of the orientation, one would expect that intercept size measurements in such a plane over all directions would result in similar estimates of size. Indeed, this is the case. In the XY plane there are no significant differences among directions for intercept size (TABLE 1). In the XZ plane, since there is a preferred orientation and its range is from 130° to 220°, one would expect relatively larger intercept size values in these directions whereas, in the directions 40° to 130°, minimum estimates would be expected, and this is the case.

Although the hypothesis of uniformity is accepted in the YZ plane, there appears to exist a tendency for preferred orientation in the directions 160° to 200°. If this were a real concentration of long axes pointing essentially in the same direction, then the maximum and minimum intercept size values should coincide with the directions 160° to 200° and 20° to 160°, respectively. This exactly the case.

Thus, orientation varies significantly from plane to plane within a rock. This is a function of the shape of the grains and the orienting

processes. The results in plane XZ, a plane containing the general direction of transport of these sediments, indicates stability with an imbrication angle downward from the horizontal in the dip direction. This result coincides with Rusnak's theoretical and experimental results (1957). Thus, with respect to the parameter orientation, we conclude that significantly different results are obtained from different thin sections, due basically to the depositional processes operating on the grain.

Packing analysis. P_d average values for different faces and directions within faces are summarized in TABLE 3. Examination of these values for slides indicates close agreement among the values. This is corroborated by the analysis of variance in TABLE 5.

The average values for directions within traverses present a more complex problem. The differences in magnitude among directions are significantly different, as indicated in TABLES 3 and 5. Thus, P_d varies not only in magnitude but with direction. Packing is unquestionably an anisotropic property of this sediment.

Petrofabrics, structural petrology, and packing. Before any attempts are made to offer explanations for the anisotropic behavior of the textural property packing, a discussion of the relationship among petrofabric analysis, structural petrology, and packing is essential.

Petrofabric analysis is concerned with a study of the internal structure of rocks. Structural petrology is the study of the internal structures of rocks with specific interest centered upon their relationship to external structures as seen in the field (Knopf and Ingerson, 1938). Studies of

TABLE 5

ANALYSIS OF VARIANCE OF PACKING DENSITY DATA

Source of variation	Degrees of freedom	Sum of squares	Mean square	F.
Faces	2	45.885	22.9450	N.S.
Directions within faces	15	1336.379	89.0920	3.98*
Traverses within directions and faces	72	1611.832	22.3866	
Total	89	2994.096		

Allowance for directions = 8.80 per cent.

N.S. = Not Significant
*Significant at the 0.001 level.

both sorts have concentrated on the textural parameter orientation. Two types of orientation studies are available, namely space-lattice orientation and dimensional orientation, or orientation by grain shape.

Petrofabric studies utilizing space-lattice orientation analyses are preferred when the directions of principal stress, which have been applied to the rocks, are to be determined (Knopf and Ingerson, 1938; Sander, 1948, 1950; and De Sitter, 1956*b*). Neither petrofabric analysis nor structural petrology presupposes that this type of orientation is the unique textural parameter that can determine applied stress direction. Certainly, it is one parameter that might be affected in varying degrees, but what of other textural parameters?

The textural parameters of a sediment are size, shape, orientation, and packing. On a priori grounds, which of these parameters might reflect applied directional forces, diagenetic or postdiagenetic? Shape and size can be rejected since they reflect provenance and transportation perturbations. Orientation is a possibility; however, the experimental work discussed above indicates that, in this sediment, dimensional orientation reflects depositional rather than applied stress adjustments. Packing thus appears to be the most likely candidate.

Little work on the subject of packing had been undertaken until recently. Interest was not focused on packing as a variable capable of reflecting applied stress. The results of this current work present an opportunity to focus attention on packing as an index of applied stress, and it is in this light that the packing anisotropicity is interpreted.

The assumption is made that, if stresses are applied to a sediment when the grains are not as yet fixed in space, the grains will react to these applied forces by moving in the direction or directions of applied force. This movement of grains along the directions of stress will result in relatively larger packing values in some directions than in others. That is, in the directions of applied stress, the grains will be closer together and more grains will be found in these directions than in others.

Planes of maximum packing. In the search for the maximum P_d values, it was recognized that there existed more than one direction within a thin section that demonstrated a maximum value. Since no clear-cut rationalization presented itself for selecting one value over any other, and since no previous work had been done for guidance, only the two highest maximum P_d values were selected, and planes of maximum packing density were prepared from these values.

Procedure for determining planes of maximum packing. Maximum P_d values were selected from the thin sections that had been cut orthogonal to the bedding planes, since in the XZ and YZ planes the significant differences among directions existed.

The cube of the rock represents a portion of a fold that, when the bedding plane is held horizontal, has been rotated through its dip angle. The strike direction of the specimen is N65°E. Thus, any traverse

direction in the YZ plane associated with a maximum P_d value may be plotted on a stereonet (Bucher, 1944) as an apparent dip of a plane of maximum packing. Similarly, any direction in the XZ plane, perpendicular to YZ, may be plotted as an apparent dip of a plane of maximum packing. The stereonet may then be utilized to find the true dip and strike of the plane of maximum packing. This plane may then be rotated back to its present position in space and its strike may then be considered the field manifestation of the direction of applied stress.

The various combinations of maximum packing values for the XZ and YZ planes are indicated in TABLE 6. The planes of maximum packing, rotated to their present field position, are indicated in FIGURES 4*a*, *b*, c, and *d*.

TABLE 6

MAXIMUM PACKING DENSITY FOR PLANES XZ AND YZ, THEIR DIRECTIONS WITHIN THIN SECTIONS AND THEIR APPARENT DIP.

Plane: XZ			
Direction within thin section	P_d (per cent)	Apparent dip	Direction
30° 60°	64.52 65.66	30°NW 60°NW	N25°W N25°W
Plane: YZ			
Direction within thin section	P_d (per cent)	Apparent dip	Direction
60° 120°	63.87 64.40	60°SW 60°NE	S65°W N65°E

Interpretation of diagrams and significance of planes of maximum packing. The strikes of the planes of maximum packing, when rotated to their present spatial positions, all trend SE-NW. The symmetrical disposition of these planes about a line perpendicular to the strike of the bedding is illustrated in FIGURE 5. There thus exists a remarkable correlation between the strikes of the planes of maximum packing and the direction of the forces that deformed the Appalachian Mountains.

Thus, it would appear that the anisotropic behavior of packing is a function of the forces applied to the sediment after deposition – in this case clearly tectonic forces – and not, as was the case with intercept size and dimensional orientation, a function of transportation,

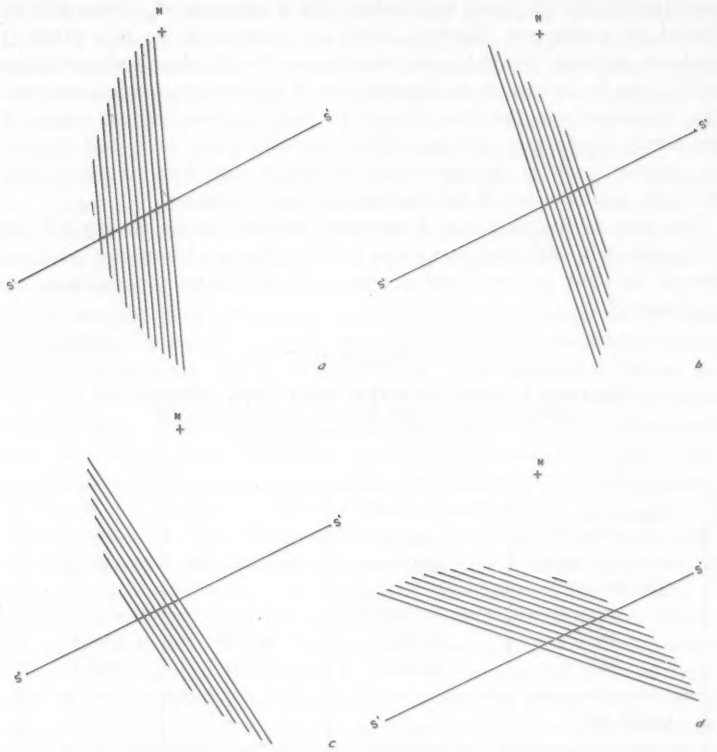

FIGURE 4. Stereographic projection of planes of maximum packing rotated to present field position. S'-S' represents the strike of the Pottsville sandstone. N = true north. Combinations of apparent dips prior to rotation: (*a*) 60°NW (in a direction N25°W), 60°SW (in a direction S65°W). (*b*) 30°NW (in a direction N25°W), 60°NE (in a direction N65°E). (*c*) 30°NW (in a direction N25°W), 60°SW (in a direction S65°W). (*d*) 60°NW (in a direction N25°W), 60°NE (in a direction N65°E). Attitude of planes after rotation: (*a*) S5°E, 42°W. (*b*) S18°E, 56°E. (*c*) S28°E, 58°W. (*d*) S47°E, 45°E.

deposition, and provenance. It is not inappropriate, therefore, to reflect upon the significance of these results.

An examination of FIGURE 5 suggests an association between the planes of maximum packing as determined from thin section analysis and the megascopic fractures and joints resulting from forces in general. No field work was done to correlate the direction and attitude of the joints and fracture patterns of the Pottsville with the planes of maximum packing. However, it is well known that forces applied to rocks will

manifest themselves in rupture or fracture surfaces. In the case of compressive forces, for example, pairs of fracture surfaces may result, and these surfaces will make an angle with the direction of the compressive force. What is it that determines this angle? Is it random? That is, will identical rocks under identical compressive conditions produce fracture surfaces that make any angle with the force direction? Generally speaking, the angle is not random, but varies from lithology to lithology (Billings, 1958; De Sitter, 1956*b*), as Griffiths implied in 1952 (*op. cit.*, 1952).

Thus, on the basis of the following: (1) the spatial attitude of the planes of maximum packing; (2) the relationship between the planes of maximum P_d and the direction of Appalachian folding; (3) the general known relationship between applied compression and resultant fracture and joint patterns; and (4) the relationship between lithology and the angle between the direction of compression and the shear planes, I propose the hypothesis that the presence or absence of fractures in sediments is purely a function of the anisotropicity of those textural parameters which are capable of reflecting applied stress. Only further studies of the Pottsville, as well as other sediments, recent or ancient, will test the above hypothesis as well as determine the uniqueness of the parameter packing.

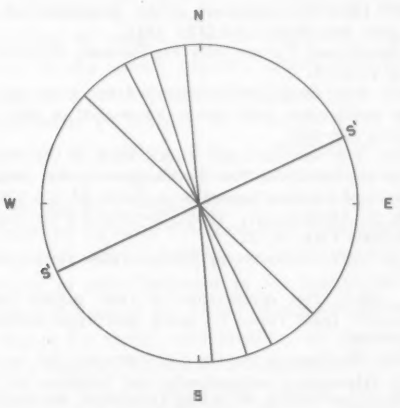

FIGURE 5. Graphic representation of the relationship between the strikes of the planes of maximum packing and the strike of the bedding plane.

Summary

These preliminary results indicate the anisotropicity of the variables, size, orientation, and packing. The anisotropicity is shown to be a function of the measurement techniques, interrelationships among textural

parameters, sedimentary processes, diagenesis, tectonics, and sampling procedures.

Intercept size is not recommended as an estimator of the parameter size, since it is interrelated complexly with orientation and shape. Orientation should be measured in nonrandom planes of rock, preferably oriented with respect to a significant axis. Packing should be measured neither in random thin sections nor in random directions within thin sections. Meaningful estimates will be made only when specific planes are oriented in space and specific directions are oriented within planes.

Finally, a hypothesis is presented that attributes the fractures of a sediment to those textural parameters that are capable of reflecting applied stress.

References

BILLINGS, M. P. 1958. Structural Geology. 2nd ed. Prentice Hall. Englewood Cliffs, N. J.

BUCHER, W. H. 1944. The steriographic projection, a handy tool for the practical geologist. J. Geol. 52 (3): 191-192.

CHAYES, F. 1950. Measurements of intercept distances in thin section. Trans. Am. Geophys. Union. 31 (6): 870-872.

DE SITTER, L. U. 1956*a*. Structural Geology. : 12-17. McGraw-Hill, New York, N. Y.

DE SITTER, L. U. 1956*b*. Op. cit. :122-133.

FEDERER, W. T. 1955. Experimental Design. :29. Macmillan. New York, N. Y.

GRIFFITHS, J. C. 1952. Measurement of the properties of sediments. Abstr. Bull. Geol. Soc. Am. Part 2. 63 (12): 1256.

HALD, A. 1952. Statistical Theory with Engineering Applications. :742. Wiley & Sons, New York, N. Y.

KAHN, J. S. 1956*a*. The analysis and distribution of the properties of packing in sand size sediments. 1.On the measurement of packing in sandstones. J. Geol. 64 (4): 385-395.

KAHN, J. S. 1956*b*. The analysis and distribution of the properties of packing in sand size sediments. 2.The distribution of the packing measurements and an example of packing analysis. J. Geol. 64 (6): 578-606.

KNOPF, E. B. & E. INGERSON. 1938. Structural Petrology. Geol. Soc. Am. :20. Mem. 6. New York, N. Y.

PETTIJOHN, F. J. 1957. Sedimentary Rocks. :159. Harper & Bros. New York, N. Y.

RUSNAK, G. A. 1957. The orientation of sand grains under conditions of "unidirectional" fluid flow. 1.Theory and experiment. J. Geol. 65 (4): 338-396; 384-409.

SANDER, B. 1948. Einführung in die Gefügekunde der geologischen Körper. Erster Teil. Allgemeine Gefügekunde und Arbeiten im Bereich Handstück bis Profil. Springer-Verlag. Wien und Innsbruck, Austria.

SANDER, B. 1950. Einführung in die Gefügekunde der geologischen Körper. Zweiter Teil. Die Korngefüge. Springer-Verlag. Wien und Innsbruck, Austria.

THE NEW YORK ACADEMY OF SCIENCES

SECTION OF BIOLOGICAL AND MEDICAL SCIENCES

CONTRAST AND STABILITY IN THE NERVOUS SYSTEM*

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Contrast and stability appear to be unrelated properties of the nervous system. However, an inhibitory mechanism will be discussed that not only affects precision of representation of the environment and of motor responses, but also prevents escape of sensory and motoneurons from controlled activity into seizurelike excess. It is not suggested that this mechanism alone is responsible for control of these properties, but that it plays a part in it.

Neurons in the central nervous system receive messages from many cells through synapses located upon cell bodies and their branches; outgoing impulses, traveling along axons, reach many other cells. Thus provision is made for mixing of excitatory and of inhibitory influences, as well as for spatial and temporal summation. The excitability of neurons fluctuates with these converging synaptic events. Most cells respond in typical patterns that range from one or several outgoing impulses in response to several arriving ones, to production of repetitive efferent discharge upon receipt of single afferent impulses. Sensory and motor cells appear to act in the former manner, albeit with great variability, whereas certain interneurons belong to the latter type. Strong excitation of groups of cells tends to involve in response even greater numbers than those originally stimulated, due to summation of excitation on neurons in the subliminal fringe. In this connection it may be of significance that often groups of synergistic cells are located close together, and usually are separated by some distance from antagonistic groups. This anatomical point is well established for the cat's spinal cord (Romanes, 1951). The evidence is only fragmentary for tangential distribution in the cat's motor cortex (Chang *et al.*, 1947) or sensory cortex (Mountcastle, 1957), but it is firmer for radial distribution, as shown in the detailed analysis of the cat's sensory cortex by Mountcastle (1957). There exists reciprocal inhibition between antagonistic groups, but synergistic ones usually facilitate each other (see Sherrington, 1947). How is this facilitation and consequent spread of excitation controlled? The fine adjustment of nervous activity found in nature suggests the existence of systems that tend functionally to isolate cells that anatomically are near one another.

*This paper, illustrated with slides, was the first of two papers presented at a meeting of the Section of Biological and Medical Sciences on February 9, 1959.

Contrast

The reaction of animals to their environment presupposes sensory perception, the accuracy of which depends upon the number of sensory receptors engaged and the detail of projection in the central nervous system. The anatomical sequence usually consists of peripheral receptors (that may be part of first-order sensory neurons) which, in turn, connect with second- and third-order central cells. Adjacent sense organs synapse with central cells that lie close together: the outside world is reflected from periphery to center in orderly projections. However, accuracy of representation in the central nervous system is not achieved merely by point-to-point projection, because receptive fields overlap, as first demonstrated for tactile receptors in the frog's skin by Adrian *et al.* (1931) and for ganglion cells in the frog's retina by Hartline (1940). Since the activity of sensory cells is more intense in the center of the field than near its edges, unevenly distributed peripheral disturbance causes correspondingly uneven rates of discharge of central neurons. Lorente de Nó (1933), Marshall and Talbot (1942), and Tower (1943) have pointed out that shifting overlap of receptive fields provides a basis for two-point discrimination: two peripheral sources of excitation are represented centrally by two areas of rapidly discharging cells, separated by relatively quiescent ones. The problem has been reviewed fully by Granit (1955).

However, the question remains how points separated by less than one diameter of a receptive field are distinguished. This fine resolution is brought about by neural inhibition exerted by active cells on their neighbors, as first described by Cattell and Hoagland (1931) for the frog's skin, and by Hartline (1939) for the frog's eye. This type of inhibition enhances contrast between areas of graded intensities of activity. Demonstrations of this inhibition on various pathways are discussed in the following paragraphs.

Somatosensory pathways. Cattell and Hoagland (1931) noted reduction of discharge from tactile receptors in frog's skin upon stimulation of areas adjacent to the receptive field of the test unit. They drew attention to the similarity of this effect to the interaction of antidromic and orthodromic volleys in spinal motor nuclei, reported by Eccles and Sherrington, 1931 (see *Efferent pathways*). In an analysis of pain perception, Tower (1943) described inhibition of sensory nerve discharge by stimulation of nearby sensory spots. Amassian (1954), Towe and Amassian (1958), and Mountcastle (1957) have shown that stimulation of neurons in the cat's somatosensory cortex by touch or pressure on the skin, or by rotation of joints, can be inhibited by stimulation of adjacent areas. Mountcastle (1957) named this phenomenon "afferent inhibition," and suggested its probable function in the improvement of sensory contrast over that afforded by spinal mechanisms. It is not known how much of the inhibition occurs on the afferent path to the cortex.

The visual pathway. Responses recorded from frog optic nerve fibers can be inhibited by illumination of the same receptive field as that of the test unit (Hartline, 1939) or of adjacent fields (Barlow, 1953). The same relation holds for discharges of sensory ommatidia and of their axons in the eye of *Limulus* (Hartline, 1949; Hartline, Wagner and Ratliff, 1956). The system not only can produce spatial discrimination; it can also assist in temporal resolution: responses to stable as well as to transient illumination are modulated by mutual inhibition of neighboring cells (Ratliff *et al.*, 1958). Kuffler (1952, 1953) has described this type of inhibition in the cat's retina: discharge of ganglion cells can be inhibited by conditioning illumination of cells in the periphery of the receptive field of the test ganglion cell or of adjacent fields.

The auditory pathway. Mutual inhibition of neighboring cells has been demonstrated at various levels. Galambos and Davis (1944) noticed that activity of single auditory nerve fibers of the cat, elicited by sounding pure tones, could be inhibited by tones of similar frequencies. The interaction occurred most likely between sensory hair cells in the cochlea or between the first-order bipolar neurons receiving impulses from them. The same phenomenon was observed for the outflow from the cat's cochlear nucleus by Whitfield (1955) and Katsuki and Watanabe (1958). Whitfield (1956) has pointed out that this effect helps to maintain the identity of two tones sounded simultaneously. Katsuki *et al.* (1956) also found this sort of interaction between cells in the cat's medial geniculate body.

Efferent pathways. Stretch of a muscle elicits a highly localized response: the monosynaptic reflex tends to activate only those muscles, or their parts, from which afferent stretch messages have arisen (Liddell and Sherrington, 1924; Lloyd, 1943). This accuracy of the reflexes homing on the main target (homonymous reflexes) is achieved primarily by the preponderance of appropriate excitatory connections, but the afferent fibers do have a branched distribution. Why, then, are the reflexes reaching lesser targets (heteronymous reflexes) smaller than might be expected on the basis of anatomical paths available? Sherrington's demonstration (1929) that motoneurons can be made refractory, that is, be occluded, by volleys impinging on other neurons in the same pool was followed by the observation of Eccles and Sherrington (1931) that antidromic activation of motoneurons can reduce the excitability of the pool. The search for the mechanism led to Renshaw's discovery (1941) of inhibition exerted by active motoneurons on their neighbors, even in adjacent pools (see *The Inhibitory System*, below.) Brooks and Wilson (1959) have shown that this inhibition partially maintains the accurate distribution of stretch reflexes. Since stretch reflexes subserve posture and also volitional movement, the detailed confinement of these reflexes to their paths of afferent origin probably aids in the execution of fine movement.

The same situation as applies to spinal (lower) motoneurons also

applies to cortical (upper) motoneurons: discharge of a cell can inhibit spontaneous or evoked activity of surrounding cells. Phillips (1956a, 1959) and Brooks (1959) have demonstrated this point in the cat's sigmoid gyri by selectively activating pyramidal cells adjacent to those tested. The relation between this cortical inhibition and "afferent" inhibition still awaits study.

The Inhibitory System

The nonspecific inhibition of spinal motoneurons produced by action of their neighbors (Renshaw, 1941) was shown by Renshaw (1946) to be accompanied by repetitive discharge of interneurons in the ventral horn, lasting approximately for the duration of inhibition. Eccles *et al.* (1954) discovered the cholinergic nature of the synaptic connection between recurrent motoneuron axon collaterals and these interneurons, and named them Renshaw's cells. Brooks, Curtis and Eccles (1957) showed that their inhibitory transmitter is most likely the same as that of all other spinal inhibitions. The history of this system has been reviewed extensively by Eccles (1955) and also, briefly, by Brooks and Wilson (1959) in connection with their demonstration that Renshaw's reflex inhibition can be varied with cholinergic drugs, as can the excitability of Renshaw's cells. Granit *et al.* (1957) and Brooks and Wilson (1959) proposed the term "recurrent" to replace the name "antidromic" inhibition. However, although Renshaw's cells were thought to act only nonspecifically over short distances, the pathway of recurrent inhibition appears also to be involved in patterned reflex interactions, both facilitatory and inhibitory, some of which span greater distances (Wilson, 1959; Wilson *et al.*, 1959). Granit *et al.* (1957) have demonstrated the influence of higher centers on recurrent inhibition. The system is thus revealed to take part in many functions.

The similar inhibition among adjacent pyramidal cells in the cat's cerebral cortex also likely involves recurrent collaterals (Phillips, 1959; Brooks, 1959), but cortical inhibitory interneurons have so far failed of demonstration. The possibility has not been ruled out yet that the inhibition is produced at least partly by afferent volleys from thalamic neurons, activated by impulses in pyramidal axon collaterals in the thalamus. As in the case of spinal motoneurons, the collaterals of pyramidal axons also carry facilitatory messages (Chang, 1955).

The mutual inhibition between ommatidia in the eye of *Limulus*, referred to by Tomita (1958) as "lateral" inhibition, is most likely conducted through axon collaterals (Hartline *et al.*, 1956; Tomita, 1958). There is no evidence for or against interpolation of inhibitory interneurons in the system.

The pathways of all other inhibitions cited in the previous sections are unknown. However, the patterns of local interaction described suggest

the involvement of recurrent collaterals, which have indeed been shown to be ubiquitous in the central nervous system by Cajal (1952).

Stability

Reference was made earlier to the patterns of discharge of various neurons. It has been shown many times that increasing excitation leads to increased numbers of active neurons and to acceleration of their discharge, which in turn brings about intensified sensory or motor responses.

Reflexes are known to spread in the spinal cord from their paths of origin when afferent intensity or frequency are increased (Alvord and Fuortes, 1953; Lloyd, 1957). Excitation may spread back to the origin of the disturbance and, if it has recovered from refractoriness, re-excitation may occur. Burns (1958) has reviewed this consideration in support of the suggestion that spinal after-discharge is created in that manner (Forbes, 1922; Ranson and Hinsey, 1930; see also Lorente de No, 1935, on the third cranial nucleus). Recurrent inhibition, which probably affects both mono- and polysynaptic reflexes (Holmgren and Merton, 1954; Curtis *et al.*, 1957), exerts a general damping action by reduction of firing frequency and of spread of excitation (Eccles *et al.*, 1954; Granit *et al.*, 1957; Brooks and Wilson, 1959). Hammond *et al.* (1956) and Granit *et al.* (1957) have revealed the particular intensity of recurrent inhibition exerted on those motoneurons responsible for maintenance of postural stretch reflexes. These reflexes are especially prone to cumulative excitation, which leads to rigidity and spasticity if inadequately opposed. As it was shown that recurrent inhibition damps this tendency, the dual function served by recurrent inhibition has been demonstrated for the same reflexes: improvement of contrast (see above) and maintenance of stability.

The dependence of spread of excitation in the cerebral cortex upon stimulus intensity has been described (Adrian, 1936; Burns, 1950; Phillips, 1956b; Brooks and Enger, 1959); also the natural occurrence of such spread (Lilly, 1954; Lilly and Cherry, 1954). Strong repetitive discharges are known to give rise to convulsive movements (Adrian and Moruzzi, 1939). Since the intensity of cortical recurrent inhibition varies with that of pyramidal discharge, a mechanism is thus provided that stablizes function and guards against excessive firing. The similarity of experimentally induced overactivity to epilepsy has been pointed out by Penfield and Jasper (1954) and by Burns (1958). Perhaps malfunction of recurrent inhibition is a factor in the production of epilepsy.

Reviewing the evidence on contrast and stability, it is apparent that inhibition of neurons by their active neighbors occurs in projection systems generally. Although it is possible that recurrent inhibition is involved in many cases, the mechanism need not necessarily be of the type demonstrated in the spinal cord. The examples cited,

found in animals ranging from ancient arthropods to modern mammals, represent convergent evolution of *function*.

Summary

It has been found, wherever tested, that active cells in sensory or motor projection systems inhibit adjacent neurons.

It is indicated that the pathway of the inhibition involves recurrent axon collaterals for the cat's spinal motoneurons and probably for cortical motoneurons and *Limulus* ommatidia. In other cases it is unknown.

This inhibition sharpens contrast and maintains stability.

References

ADRIAN, E. D., MCK. CATTELL & H. HOAGLAND. 1931. Sensory discharges in single cutaneous nerve fibres. J. Physiol. **72**: 377-391.

ADRIAN, E. D. 1936. The spread of activity in the cerebral cortex. J. Physiol. **88**: 127-161.

ADRIAN, E. D. & G. MORUZZI. 1939. Impulses in the pyramidal tract. J. Physiol. **97**: 153-199.

ALVORD, E. C., JR. & M. B. F. FUORTES. 1953. Reflex activity of extensor motor units following muscular afferent excitation. J. Physiol. **122**: 302-321.

AMASSIAN, V. E. 1954. Studies on organization of a somesthetic association area, including a single unit analysis. J. Neurophysiol. **17**: 39-58.

BARLOW, H. B. 1953. Summation and inhibition in the frog's retina. J. Physiol. **119**: 69-88.

BROOKS, V. B., D. R. CURTIS & J. C. ECCLES. 1957. The action of tetanus toxin on the inhibition of motoneurons. J. Physiol. **135**: 655-672.

BROOKS, V. B. & V. J. WILSON. 1959. Recurrent inhibition in the cat's spinal cord. J. Physiol. **146**.

BROOKS, V. B. & P. S. ENGER. 1959. Spread of directly evoked responses in the cat's cerebral cortex. J. Gen. Physiol. **42**: 761-777.

BROOKS, V. B. 1959. Recurrent inhibition in the cat's cerebral cortex. Federation Proc. **180**.

BURNS, B. D. 1950. Some properties of the cat's isolated cerebral cortex. J. Physiol. **111**: 50-68.

BURNS, B. D. 1958. The Mammalian Cerebral Cortex. Arnold. London, England.

CAJAL, S. R. 1952. Histologie du systeme nerveaux de l'homme et des vertébrés. Rep. ed. **1**. Madrid, Spain.

CATTELL, MCK. & H. HOAGLAND. 1931. Response of tactile receptors to intermittent stimulation. J. Physiol. **72**: 392-404.

CHANG, H. T., T. C. RUCH & A. A. WARD. 1947. Topographical representation of muscles in motor cortex of monkeys. J. Neurophysiol. **10**: 39-56.

CHANG, H. T. 1955. Activation of internuncial neurons through collaterals of pyramidal fibers at cortical level. J. Neurophysiol. **18**: 452-471.

CURTIS, D. R., J. C. ECCLES & R. M. ECCLES. 1957. Pharmacological studies on spinal reflexes. J. Physiol. **136**: 420-434.

ECCLES, J. C. & C. S. SHERRINGTON. 1931. Studies on the flexor reflex. VI. Inhibition. Proc. Roy. Soc. London. **B109**: 91-113.

ECCLES, J. C., P. FATT & U. KOKETSU. 1954. Cholinergic and inhibitory synapses in a pathway from motor axon collaterals to mononeurons. J. Physiol. **126**: 524-562.

ECCLES, J. C. 1955. The central action of antidromic impulses in motor nerve fibers. Arch. ges. Physiol. Pflüger's. **260**: 285-415.

FORBES, A. 1922. The interpretation of spinal reflexes in terms of present knowledge of nerve conduction. Physiol. Revs. **2**: 361-414.

GALAMBOS, R. & H. DAVIS. 1944. Inhibition of activity in single auditory nerve fibers by acoustic stimulation. J. Neurophysiol. **7**: 287-303.

GRANIT, R. 1955. Receptors and Sensory Perception. Yale Univ. Press. New Haven, Conn.

GRANIT, R., J. E. PASCOE & G. STEG. 1957. The behavior of tonic alpha and gamma motoneurons during stimulation of recurrent collaterals. J. Physiol. **138**: 381-400.

HAMMOND, P. H., P. A. MERTON & G. G. SUTTON. 1956. Nervous gradation of muscular contraction. Brit. Med. Bull. **12**: 214-218.

HARTLINE, H. K. 1939. Excitation and inhibition of the "off" response in vertebrate optic nerve fibers. Am. J. Physiol. **126**: 527.

HARTLINE, H. K. 1940. The receptive fields of optic nerve fibers. Am. J. Physiol. **130**: 690-699.

HARTLINE, H. K. 1949. Inhibition of activity of visual receptors by illuminating nearby retinal areas in the *Limulus* eye. Federation Proc. **8**:69.

HARTLINE, H. K., H. G. WAGNER & F. RATLIFF. 1956. Inhibition in the eye of *Limulus*. J. Gen. Physiol. **39**: 651-673.

HOLMGREN, B. & P. A. MERTON 1954. Local feedback control of motoneurons. J. Physiol. **123**: 47P.

KATSUKI, Y., H. UCHIYAMA, T. WATANABE & N. MARUYAMA. 1956. Electric responses of auditory neurons in cat to sound stimulation. II. Proc. Japan. Acad. **32**: 504-506.

KATSUKI, Y. & T. WATANABE. 1958. Electric responses of auditory neurons in cat to sound stimulation. III. Responses to two sounds delivered simultaneously. Proc. Japan. Acad. **34**: 64-69.

KUFFLER, S. W. 1952. Neurons in the retina: organization, inhibition and excitation problems. Cold Spring Harbor Symposium Quant. Biol. **17**: 281-292.

KUFFLER, S. W. 1953. Discharge patterns and functional organization of mammalian retina. J. Neurophysiol. **16**: 37-68.

LIDDELL, E. G. T. & C. S. SHERRINGTON. 1924. Reflexes in response to stretch (myotatic reflexes). Proc. Roy. Soc. London. **B96**: 212-242.

LLOYD, D. P. C. 1943. Conduction and synaptic transmission of reflex response to stretch in spinal cats. J. Neurophysiol. **6**: 317-326.

LLOYD, D. P. C. 1957. Temporal summation in rhythmically active monosynaptic reflex pathways. J. Gen. Physiol. **40**: 427-434.

LILLY, J. C. 1954. Instantaneous relations between the activities of closely spaced zones on the cerebral cortex. Am. J. Physiol. **176**: 493-505.

LILLY, J. C. & R. B. CHERRY. 1954. Surface movements of click responses from acoustic cerebral cortex of cat: leading and trailing edges of a response figure. J. Neurophysiol. **17**: 521-532.

LORENTE DE NÓ, R. 1933. Studies on the structure of the cerebral cortex. J. Psychol. Neurol. Lpz. **46**: 113-177.

LORENTE DE NÓ, R. 1935. Facilitation of mononeurons. Am. J. Physiol. **111**: 505-528.

MARSHALL, W. H. & S. A. TALBOT. 1942. Recent evidence for neural mechanisms in vision leading to a general theory of sensory acuity. Biol. Symposium **7**: 117-164.

MOUNTCASTLE, V. B. 1957. Modality and topographic properties of single neurons of cat's somatic sensory cortex. J. Neurophysiol. **20**: 408-434.

PENFIELD, W. & H. H. JASPER. 1954. Epilepsy and the Functional Anatomy of the Human Brain. Little, Brown & Co. Boston, Mass.

PHILLIPS, C. G. 1956a. Intracellular records from Betz cells in the cat. Quart. J. Exptl. Physiol. **41**: 58-69.

PHILLIPS, C. G. 1956b. Cortical motor threshold and the thresholds and distribution of excited Betz cells in the cat. Quart. J. Exptl. Physiol. **41**: 70-84.

PHILLIPS, C. G. 1959. Actions of antidromic pyramidal volleys on single Betz cells in the cat. Quart. J. Exptl. Physiol. **44**: 1-25.

RANSON, S. W. & D. C. HINSEY. 1930. Reflexes in hind limbs of cats after transection of spinal cord at various levels. Am. J. Physiol. **94**: 471-495.

RATLIFF, F., W. H. MILLER & H. K. HARTLINE. 1958. Neural interaction in the eye and the integration of receptor activity. Ann. N. Y. Acad. Sci. **74**(2): 210-222.

RENSHAW, B. 1941. Influence of discharge of motoneurons upon excitation of neighboring motoneurons. J. Neurophysiol. **4**: 167-183.

RENSHAW, B. 1946. Observations on interaction of nerve impulses in the gray matter and on the nature of central inhibition. Am. J. Physiol. **146**: 443-448.

ROMANES, G. J. 1951. The motor cell columns of the lumbosacral spinal cord of the cat. J. Comp. Neurol. **94**: 313-358.

SHERRINGTON, C. S. 1929. Some functional problems attaching to convergence. Proc. Roy. Soc. London. **105B**: 332-362.

SHERRINGTON, C. S. 1947. The Integrative Action of the Nervous System. Cambridge Univ. Press. Cambridge, England.

TOMITA, T. 1958. Mechanism of lateral inhibition in eye of *Limulus*. J. Neurophysiol. **21**: 419-429.

TOWE, A. L. & V. E. AMASSIAN. 1958. Patterns of activity in single cortical units following stimulation of the digits in monkeys. J. Neurophysiol. **21**: 292-311.

TOWER, S. S. 1943. Pain: definition and properties of the unit for sensory reception. Research Publ. Assoc. Nervous Mental Diseases. **23**: 16-43.

WILSON, V. J. 1959. Recurrent facilitation of spinal reflexes. J. Gen. Physiol. **42**: 703-713.

WILSON, V. J., W. H. TALBOT & F. P. J. DIECKE. 1959. Patterns of recurrent conditioning of spinal reflexes. Nature. In press.

WHITFIELD, I. C. 1955. Two-tone inhibition at the trapezoid body level. J. Physiol. **127**: 15-16P.

WHITFIELD, I. C. 1956. Electrophysiology of the central auditory pathway. Brit. Med. Bull. **12**: 105-109.

II. SIMULTANEOUS RECORDING OF THE ACTIVITIES OF SEVERAL INDIVIDUAL CORTICAL NEURONS*

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One important objective in recording the activity of individual members within a group of central neurons is the determination of the instant-to-instant distribution of discharges and the changes in distribution induced by peripheral stimulation. Such information usually cannot be obtained by recording the combined activities of many neurons with a gross electrode resting on the surface of the brain or within the brain, because the electric waves thus recorded are presumably composed of both discharges and graded nonpropagated responses of various portions of the neurons mixed in unknown proportions. Only in special instances, for example, in sampling the discharges of the axons composing a tract, can one form of activity (discharge) within the group be inferred. However, the difficulties in drawing conclusions about the group from a single neuronal analysis are numerous. A tendency toward sampling the activity of large rather than small neurons is often present because of the greater likelihood of damaging small neurons with even the smallest recording electrodes. Only a limited number of individual neurons can be sampled one at a time during the total course of an experiment of many hours' duration; furthermore, the general condition of the animal probably changes during the course of the experiment. This limits the value of "spatiotemporal" diagrams of activity such as those constructed for the midbrain reticular formation,[1] which were obtained by combining observations on different neurons taken at different times during a given experiment. Fortunately a conclusion drawn from the spatiotemporal diagrams could also be tested by simultaneously recording the activities of two neurons with a single microelectrode.[1] Such double unit preparations have been illustrated in previous studies of single cortical neurons.[2-4] However, recording the activity of two cortical neurons with a single microelectrode is a fortunate accident rather than a basis for a systematic survey, and the smaller the electrode used, the less often is such a recording obtained. Furthermore, when discharges in the two neurons are coincident, interpretation of the record is ambiguous precisely where an important relationship in time may be present. Recording the activities of two or more neurons on two or more separate channels avoids the above disadvantages. In addition. simultaneous recordings from several individual neurons permits estimation of the

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coherence of the variations of behavior, for example, latency, in the neurons recorded. Such information is indispensable before conclusions can be drawn from spatiotemporal diagrams of activity about the precision of the intervals between discharges of different neurons, and cannot be obtained by recording from an individual neuron at a time.

We shall describe a technique for independently manipulating three microelectrodes through a limited volume of cortex and recording the activity of at least three individual cortical neurons. Cerebral pulsations in phase with the heart beat and respiration were avoided in an earlier study of single cortical neurons by introducing the microelectrode through a hole in a plexiglass plate that lightly pressed on the cortex, combined with cisternal drainage of cerebrospinal fluid.[2] This technique seemed too clumsy to be adapted to multiple electrode exploration. We used, therefore, a modification of the "closed head" technique,[3, 5] which employs the principle[6] that cardiovascular and respiratory pulsations of the brain are reduced when the intracranial cavity is perfectly sealed against the external atmosphere. Instead of inserting a microelectrode into the brain by means of a microdrive attached to the skull, high melting point (60 to 65° C.) paraffin wax is used to make a watertight and airtight seal around glass micropipettes that are externally and independently manipulated. The technique employs a chamber consisting of a lucite cup and a metal ring (FIGURE 1). The bone is

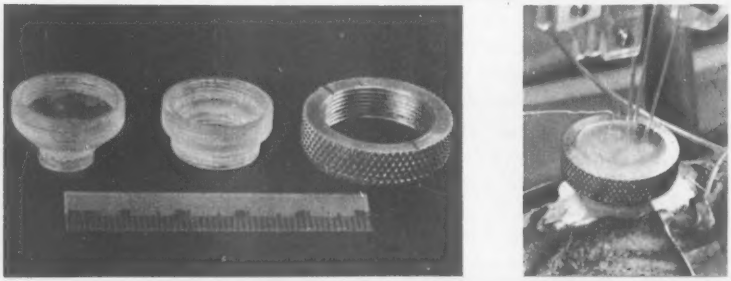

FIGURE 1. "Closed head" chambers. Photographs from left show lucite cup for cat and monkey, and brass ring. Centimeter rule below. Right photograph obtained from experiment on cat where three microelectrodes were inserted into cortex and silver ball electrode recorded the electrocorticogram.

freed from periosteum and carefully dried over the portion of cat or monkey cortex that is to be explored. The cup is inserted into a trephine hole, which is bevelled at the edge, and fixed in position with dental cement. The dental cement that is initially applied should be very runny, so that the space between cup and bone is filled. When the dental cement has hardened, more dental cement of thicker consistency is applied so as to strengthen the union of cup to bone. The headholder is then

orientated so as to level the cup. The cup is then partially filled with airfree mineral oil. The epidural space is carefully explored and any air bubbles are removed. Before removing the exposed dura of the cat, it is advisable to take the following precaution against herniation of the brain through the trephine hole. A hypodermic needle is connected by polyethylene tubing to a 3-way stopcock and a reservoir. The system is filled with Locke's solution. The needle is bent close to the tip so that it can be inserted through the dura and rest transversely in the cisterna magna. Enough of a 3 per cent solution of agar agar (cooled to about 40° C.) is applied to the exterior of the dura to form a pool. The purpose of the agar agar when set is to reduce the possibility of leakage of cerebrospinal fluid around the needle and to impede any pulsation of the dura (the agar agar can be replaced by blood that is allowed to clot around the needle.) The fluid level in the reservoir is adjusted to, or slightly below, the level of the exposed dura in the cup. Cerebrospinal fluid should slowly enter the reservoir via the cisternal tap and must not be rapidly removed, for example, by vigorous suction with a hypodermic syringe. Although rapid removal of the cerebrospinal fluid initially causes the cortex and the exposed dura to fall away from the cup, brain swelling and herniation usually develop during the next few hours and cannot then be reversed by attempting to remove cerebrospinal fluid through the cisternal needle (because fluid can still be injected into the cisternal space, it appears likely that a valvelike hydrocephalic block develops in such preparations). By contrast, ventricular block and brain herniation fail to occur by the end of the experiment 20 hours or more later, when cerebrospinal fluid is slowly removed under a small hydrostatic gradient.

The dura is excised under mineral oil. Cerebrospinal fluid above the exposed cortex is removed either by slow loss through the cisternal tap, or by suction applied through the cup. It is essential at all times to keep enough mineral oil above the cortex to prevent entry of air into the subdural space. Any blood present must also be removed because of the danger of breaking the microelectrode tip, or of the formation of a gas bubble after clotting occurs.

The next step is the prewaxing of the brass ring. This is necessary to obtain an adequate union of metal and wax. The ring is heated in a bunsen flame and then dropped top-end downwards onto a slab of paraffin wax. When it is nearly buried in the molten wax, it is removed, inverted, and allowed to cool. The lowest thread is cleansed of wax with a sharp point, and the ring is then carefully screwed onto the lucite cup. As the ring is screwed down, wax is expressed from the threads and an adequate seal is formed.

The micromanipulators are conveniently mounted on a single horizontal rod, which can be rotated and clamped at each end to the head-holder. Thus the tips of the glass microelectrodes can be brought to

approximately the upper level of the metal ring and, subsequently, swung out of the way when not in use. The microelectrodes are drawn from uniform-bore glass tubing with an outside diameter of about 1 mm. to a tip diameter of 0.5 to 1.5μ,[7] and filled with 3 M KC1. The outside of the microelectrode is dried prior to use. In our later experiments, a light silver wire with a ball at the end was also introduced into the cup and positioned onto the pial surface to record the electrocorticogram. During the development of the technique, a capillary tube connected to a strain gauge/manometer, and a thermistor were introduced into the cup in order to measure the fluid pressure and the fluid temperature immediately above the cortex.

Mineral oil at room temperature is added until about the top of the lucite cup is reached. The microelectrodes are independently manipulated into the mineral oil until the level of oil in the cup is above the commencement of the uniform bore of the microelectrodes. Molten wax is then carefully run onto the surface of the mineral oil up to the top of the metal ring, care being taken that no bubbles are trapped between the oil and the wax. The wax must be applied at sufficient temperature to flow over the surface of the oil before hardening occurs. If the hydrostatic pressure in the cup is continuously recorded during application of the wax, pressure changes occurring with the heart beat and with respiration are observed to increase as the wax cools and hardens. We feared initially that it would be necessary to introduce a "refrigeration" system for the cortex. However, with practice, the level of mineral oil can readily be adjusted prior to sealing with wax so that the temperature of the fluid above the brain does not exceed 40° C. (if a mistake is made, cooled Lock's solution can readily be introduced below the hot wax through the capillary tube). We have tested a variety of waxes for sealing, ranging in melting point from about 52° C. to 65° C. Overheating of the cortex is not a limiting factor when waxes with melting points in this range are used, probably because the thick metal ring used is a good heat sink and because the brain is separated by many millimeters of poorly conducting oil from the hot wax. Household wax with a melting point in the range of 60° C. to 65° C. is satisfactory. Lower melting point waxes are too soft at body temperature to give a rigidly closed head.

The microelectrodes can usually be independently manipulated through cortex and subcortex for 10 hours or more without fluid leakage. If a fluid leak develops, resealing is readily accomplished by locally melting the wax with a hot piece of metal.

Contact of each microelectrode tip with the pia is signaled by an artefact. (A possible error in estimating the surface of the cortex is introduced when appreciable amounts of cerebrospinal fluid separate the pia from the mineral oil. Nevertheless, a contact artefact can also be observed even when, as in our earlier experiments, air-free Locke's

solution is introduced into the cup instead of mineral oil.) Subsequently, "membrane noise"[2, 8] and cortical neuronal action potentials appear within a few hundred microns depth. Consistently, the activities of 3 individual neurons can be recorded with 3 microelectrodes and, since two cortical neurons can occasionally be recorded at a single microelectrode position, we have recorded, by careful manipulation, from as many as 5 individual neurons simultaneously. As many as 5 objects (including 3 microelectrodes) traversing the wax seal do not lead to structural instability of the seal, which implies that more than 3 microelectrodes could be driven independently through a limited volume of cortex if the manipulators were appropriately grouped around a ring. An important limiting factor in the use of several microelectrodes is the variable amount of deformation of cortex induced by manipulation of any of the microelectrodes. At one extreme, a neuron can be recorded at a given electrode position without adjustment despite manipulation of the other 2 electrodes. However, careful adjustment of any microelectrode that is recording from a neuron is usually required during manipulation of the other microelectrodes. The activity recorded with all 3 microelectrodes was routinely monitored on the oscilloscopic beams and on a loudspeaker during micromanipulation. Sequential adjustment of the manipulators permitted the recording from a given cortical neuron for over 4 hours despite the movement through the cortex of the other 2 microelectrodes.

Fresh penetrations through another region of cortex are made by withdrawing the microelectrodes, unscrewing the metal ring with its adherent wax plug, and repeating the procedure of rewaxing. With practice, this operation can be performed within 10 min.

The remaining technical details are briefly as follows: The microelectrodes are independently connected to conventional cathode followers and R.C. coupled preamplifiers. A channel of D.C. amplification was available for proof of intracellular recording with one of the microelectrodes. Until recently, the action potentials were photographed from a twin gun cathode ray oscilloscope. An external beam splitter was fed onto one of the beams, yielding 3 beams in all. Better definition of the action potential contours was obtained by replacing the above system with four 3-inch cathode ray oscilloscopes. The electrocorticogram is displayed on the fourth channel. The sweep for the fourth channel lasts 1.3 sec. and is initiated 1.0 sec. before the other 3 channels. This permits observation of the background spontaneous activity prior to introducing a peripheral stimulus. Three electronic chronometers were available for accurate measurement (plus or minus 10 μ sec.) of the latency and first 2 intervals of the repetitive response of a given neuron,[1] or for the measurement of the latencies of responses of 3 neurons that are recorded with 3 microelectrodes.

Either electrical or mechanical stimulation of the periphery was used. Rectangular pulses of 0.05 to 0.75 sec. duration were applied

through bipolar needles inserted into the pads of the digits or through the skin.

Both cats and monkeys were used. The majority of the cats were initially anesthetized intraperitoneally with sodium thiopentone (usually 50 mg./kg. of body weight). The cut margins of the skin and deeper tissues were infiltrated with 1 per cent procaine. The animals were subsequently paralyzed with Flaxedil and artifically ventilated. The expired carbon dioxide concentration was measured with a rapid infrared analyzer. In general, when a cat is ventilated with air sufficiently to produce obvious chest movements, the expired carbon dioxide level is often as low as 2 per cent. In order to minimize hypocapnia and hypoxia, the animals were ventilated with 100 per cent oxygen and the tidal volume was reduced until the expired carbon dioxide level reached a 4 to 5 per cent concentration.

Examples of the experimental procedures together with the results obtained are given below. FIGURE 2 shows spontaneous discharge in cortical neurons recorded with 3 microelectrodes in somatosensory

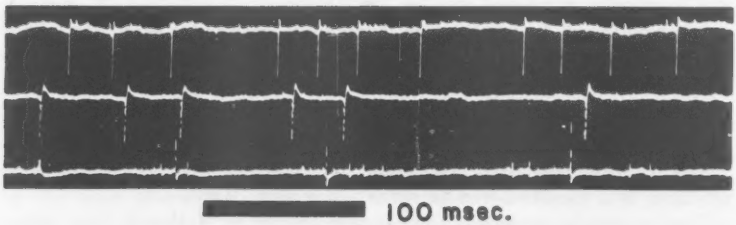

FIGURE 2. Spontaneous activity recorded with three microelectrodes. Cat initially anesthetized with sodium pentobarbital and thiopentone. Top neuron recorded at depth of 1,700 μ. Middle neuron recorded at 870 μ. Bottom neuron recorded at about 1 mm. depth. All neurons recorded in somatosensory area I. Dotted appearance of middle and bottom spikes due to split beam. Note poor reproduction of the fast negative spike in bottom beam due to use of split beam. In all figures, read records from left to right. Positivity of microelectrode signaled by downward deflection.

area I of the cat. Spontaneous discharge in cortical neurons is frequently encountered in cats that are studies many hours after barbiturate administration has been stopped. Its presence complicates the analysis of the effects of changing either the site or the intensity of peripheral stimulation. FIGURE 3 shows the effect of stimulating separately digits II, III, and V of the contralateral forepaw. Samples of spontaneous activity in the three positive-negative spikes are shown at the left. Spontaneous activity occurred neither at the same rate, nor was it synchronous in the 3 neurons. The distribution of spikes recorded from

"top" and "bottom" neurons following peripheral stimulation differed markedly from the distribution of the spontaneous spikes along corresponding portions of the sweep. Stimulation of the digits thus altered the timing of top and bottom discharges. Furthermore, inspection of TABLE 1 reveals that the alterations in timing are not identical when the responses to stimulation of the different digits are compared. The calculated interval between the median time of appearance of the top and the bottom spike was −7.5 msec. following stimulation of digit II. The corresponding intervals following stimulation of digits III and V were −0.8 msec. and −1.8 msec. respectively. The behavior of the middle neuron is more difficult to characterize. Analysis of the pooled data indicated that discharges of the middle neuron recorded with and without stimulation were not drawn from a single population. This suggests that the distribution of spikes of the middle neuron is altered by peripheral stimulation as compared with the spontaneous distribution. However, the data do not permit any differentiation according to the site of stimulation (the significance of measuring the intervals between discharges of different neurons is discussed elsewhere[1, 9]).

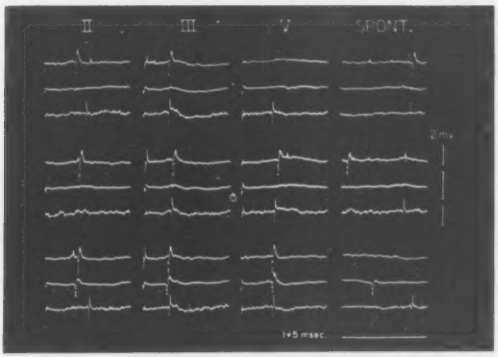

FIGURE 3. Effect of stimulation of different forelimb digits on three spontaneously active cortical neurons. Three sample records (in a vertical column) are shown for each stimulus site and for the spontaneous activity. Cat was initially anesthetized with thiopentone. All neurons recorded in forelimb area I contralateral to the stimulus site. Top neuron recorded at a depth of 1,140 μ, middle neuron at 1,580 μ, and bottom neuron at 1,300 μ.

FIGURE 4 and TABLE 2 show the effects of changing both the position and the intensity of the peripheral stimulus on the probability of occurrence of the positive-negative spikes recorded with 2 microelectrodes. Stimulation of the web increases the probability of discharge of both cortical neurons. However, the input-output functions for the 2 cortical neurons differ. Such differences may contribute to the discrimination of different intensities of peripheral stimulation.

TABLE 1

DISTRIBUTION OF ALL SPIKES DURING SUCCESSIVE 4 MSEC. TIME INCREMENTS DURING THE OSCELLOSCOPIC SWEEP*

Time	0 to 4	4 to 8	8 to 12	12 to 16	16 to 20	20 to 24	24 to 28	28 to 32	32 to 36	36 to 40
Top unit										
Digits II	0	4	3	19	4	0	0	0	0	0
III	1	3	11	25	0	0	0	0	0	0
V	2	1	3	11	7	0	0	0	0	0
Spontaneous	1	1	3	2	2	1	3	5	1	1
Middle unit										
Digits II	0	1	3	6	0	0	0	0	0	0
III	1	1	5	7	0	0	0	0	0	0
V	0	0	1	6	3	1	0	0	0	0
Spontaneous	0	2	1	3	1	1	2	1	2	0
Bottom unit										
Digits II	1	1	2	1	3	19	7	5	0	0
III	0	0	0	41	8	0	0	0	0	0
V	1	0	0	20	15	9	2	0	0	0
Spontaneous	0	1	0	1	0	0	0	1	2	0

*Sweep recurrence rate maintained at 1 per 2 sec. Zero time measured from 0.3 msec. after sweep start (that is, start of shock artefact). Total number of trials (sweeps) were 35, 40, 36, and 24 for stimulation of digits II, III and V and spontaneous activity respectively (illustrated in FIGURE 3).

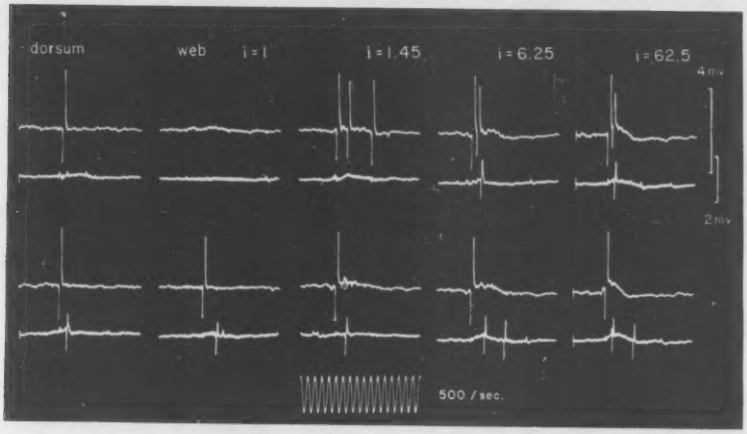

FIGURE 4. Effect of changing both the intensity and the position of the stimulus on two cortical neurons. At left, 2 sample records (in a vertical column) are shown for responses to stimulation of dorsum of forepaw. The 4 vertical columns at right show responses to stimulation of the web between digits IV and V at the indicated relative intensities in arbitrary units. Cat was initially anesthetized with thiopentone. Top neuron was recorded at a depth of 900 μ, bottom neuron at 750 μ. Both neurons recorded in contralateral forepaw area I.

TABLE 2

EFFECT OF CHANGING STIMULUS SITE AND INTENSITY ON PROBABILITIES OF DISCHARGE OF TOP (A) AND BOTTOM (B) NEURONS (ILLUSTRATED IN FIGURE 4)

Probability that Neurons A and B Discharge at Least the Indicated Number of Times Per Sweep

	P (1)		P (2)		P (3)		
	A	B	A	B	A	B	n
Dorsum	0.77	0.17	0.03	0	0	0	30
Web							
i = 1	0.60	0.35	0.30	0.05	0.05	0	20
i = 1.45	1.00	0.45	0.58	0.05	0.16	0	38
i = 6.25	1.00	0.94	0.58	0.29	0	0	31
i = 62.50	1.00	1.00	0.57	0.27	0	0	35
Spontaneous	0.17	0.04	0.04	0	0	0	23

The microelectrodes were arranged so that their tips penetrated cortex at points about 1 to 1½ mm. apart. The differences between median latencies of discharge of simultaneously recorded neurons lay between 0.25 to 147 msec. The range was reduced to 0.25 to 18 msec. when discharges in time with the secondary repetitive waves were excluded. That the median latency of response of a cortical neuron to stimulation of a given point on the periphery differs from neuron to neuron is not surprising. Previous observations on single cortical neurons sampled one at a time indicated that when the position of the peripheral stimulus was changed, the latency of neuronal discharge was altered.[2, 3, 9] However, it was not anticipated that stimulation of a given point in the forepaw would evoke nearly synchronous responses in some neurons that are separated by a distance of 1 to 1½ mm. across the cortex.

Mention must be made of an artefact that is occasionally observed when one of the microelectrodes records an action potential of several mullivolts or more amplitude. Small deflections in perfect synchrony with the large action potentials appear on one or both of the other oscilloscopic channels. Synchrony of discharge persists under varying conditions of stimulation and during spontaneous discharge. Such discharges are probably derived from the same cortical neuron as further evidenced by the disappearance of the deflections on the other channels when the large action potentials are lost due to damage to the neuron. The phenomenon is not due to interaction in the cathode followers, amplifiers or oscilloscopic equipment. In one experiment, the microelectrode that was recording the large action potentials was disconnected from its cathode follower. This did not prevent the appearance of the small deflections on another channel. The available evidence suggests that capacitative pickup between high impedance microelectrodes that lie close to one another is responsible for the interaction. (such data are not included in the range of intervals given above).

We believe that a simultaneous recording from several individual cortical neurons will prove to be a useful tool in analyzing activity in the cortex. The technique is both simple and flexible. Details such as the dimensions of the lucite cup and metal ring are not critical and can be modified to permit exploration of other areas. The depth of the cup might be increased with advantage to separate the cortex further from the hot wax. The paraffin wax closed-head technique is well suited to stereotaxic exploration because the lucite cup need not be exactly orientated with respect to the stereotaxic coordinates. An earlier form of the technique has been used for more than a year in recording from individual neurons at the midbrain level.

Acknowledgments

We are indebted to Mrs. M. G. Amassian for suggesting that mineral oil be used under the paraffin wax seal. The improvement in results was

such that we abandoned the earlier procedure in which molten wax was poured onto Locke's solution in the lucite cup.

References

1. AMASSIAN, V. E. & H. J. WALLER. 1958. Spatiotemporal patterns of activity in individual reticular neurons. *In* Reticular Formation of the Brain.:69-108. Little, Brown & Co. Boston, Mass.
2. AMASSIAN, V. E. 1953. Evoked single cortical unit activity in the somatic sensory areas. EEG clin. Neurophysiol. 5:415-438.
3. MOUNTCASTLE, V. B., P. W. DAVIES & A. L. BERMAN. 1957. Response properties of neurons of cat's somatic sensory cortex to peripheral stimuli. J. Neurophysiol. **20:** 374-407.
4. BAUMGARTEN, R. VON & K. P. SCHAEFFER. 1957. Kopplungsvorgänge an benachbarten Nervenzellen im Hirnstamm und im Motorischen Cortex der Katze. Pflüger's Arch. ges. Physiol. **265:** 264-275.
5. LI, C. L. & H. JASPER. 1953. Microelectrode studies of the electrical activity of the cerebral cortex of the cat. J. Physiol. **121:** 117-140.
6. FORBES, H. S. 1928. The cerebral circulation (1) observat. & meas. of pial vessels. Arch. Neurol. Psychiat. Chicago. **19:** 751-761.
7. LING, G. & R. W. GERARD. 1949. The normal membrane potential of frog sartorius fibers. J. Cell. Comp. Physiol. **34:** 383-405.
8. BROCK, L. G., J. S. COOMBS & J. C. ECCLES. 1952. The recording of potentials from motoneurones with an intracellular electrode. J. Physiol. **117:** 431-461.
9. TOWE, A. L. & V. E. AMASSIAN. 1958. Patterns of activity in single cortical units following stimulation of the digits in monkeys. J. Neurophysiol. **21:** 292-311.

SECTION OF PHYSICAL SCIENCES†

THE STRUCTURE OF SUPERCONDUCTORS*

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Although the phenomenon of superconductivity was discovered shortly after the turn of the century,[1] it is only recently that much serious thought has been given to the possibilities of using superdonductors extensively in any practical application. In 1956 D.A. Buck[2] emphasized a number of advantages to be realized by using superconductors to form the basic elements of a large digital computer and suggested for this purpose a particular bistable device named the cryotron. Since the publication of Buck's original paper, a number of schemes have been advanced for employing superconductors to perform both logical operations and storage functions in computers.[3-5]

An examination of the mode of operation of the contemplated superconducting devices is sufficient to indicate that high-speed, low-energy computation will be possible only if the component devices are extremely small. In general, both the power required for operation and the associated circuit time constants decrease either directly or as some power of the physical dimensions of the superconducting element, and it is apparent that substantial gains are to be realized by forming the active elements from, for example, thin films of metal.

Preliminary efforts to capitalize on the potentials held forth by the use of thin superconducting films and to incorporate thin film devices into actual complex computing circuits have brought to light a number of problems associated with these new uses. It is now apparent that many of these problems can be solved only by obtaining a better understanding of the fundamental behavior of superconducting materials. For example, many superconducting specimens are found to undergo only partial transitions into the superconducting state and to trap a considerable amount of flux in the process. The macroscopic behavior of such specimens is far from ideal. In general, the exact nature of the ideal specimen and the mechanisms responsible for observed departures from the ideal behavior are not immediately evident. The characteristics of very thin superconducting

† The Section of Chemical Sciences held a meeting on February 3, 1959, at which James K. Senior of the Kent Chemical Laboratory, University of Chicago, Chicago, Ill., presented a paper entitled "Optical Series." This paper will not be published by the Academy.

*This paper, illustrated with slides, was presented at a meeting of the Section on February 10, 1959.

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films are likewise still somewhat obscure, and it is by no means clear whether much of the observed behavior is characteristic of the intrinsic properties of films or arises because of the presence of unknown and uncontrolled imperfections or impurities in the specimen under study. A part of the work currently in progress at the IBM Research Center is concerned with the relationship between structure in superconductors and their resulting transition characteristics, and we here review a specific effort aimed at illuminating this relationship.

What constitutes the ideal behavior in a superconductor is not immediately obvious. The difficulties in setting down the specifications for an ideal specimen can be ascribed both to a lack of theoretical information as to what constitutes ideal behavior and to the fact that the very act of physically measuring the characteristics of nearly ideal specimens disturbs to some extent the quantities under observation. For example, it is believed that the transition into the superconducting state in an ideal specimen would be extremely sudden. How discontinuous this transition would actually be in an ideal specimen, however, is unknown. Pippard[6] has considered the problem and has pictured the onset of superconductivity as resulting from the growth of a superconducting nucleus latent within the material. The ability of a nucleation center to form or to exist is predicated, in Pippard's model, on the existence of some material flaw within the specimen. The ability of the nucleated region, having formed, to grow and encompass the entire specimen is dependent on the interphase surface energy present at any given moment at the boundary separating the regions of superconducting material from normal material. Very pure specimens of aluminum, for example, become superconductive with great reluctance, and pure aluminum generally can be "supercooled" to temperatures well below the normal transition temperature. In this instance, the onset of superconductivity is extremely sudden.

It might be inferred from this discussion that the nearly ideal material would show a pronounced tendency to supercool and would become superconductive only at very low temperatures, if at all. On the other hand, it has generally been assumed that the ideal superconducting transition is thermodynamically reversible. This is certainly not the case when supercooling is evident. It should be evident that the problem of defining ideal behavior is not a trivial one, and that it can be answered only through a better understanding than we now possess of some of the relationships between structure and the observed transition characteristics. In the discussion that follows we shall speak rather arbitrarily of the ideal specimen as one that meets the requirements for thermodynamic reversibility.

Not only is the transition width in a thermodynamically ideal specimen a matter of some theoretical speculation but, in addition, the *intrinsic* transition width is a difficult quantity to measure experimentally. Aside from the problems involved in physically preparing nearly ideal speci-

mens, there is the problem of ascertaining the effects of the measurements themselves on the transition width. In spite of the uncertainty as to what constitutes the ultimate ideal behavior, it is possible to prepare specimens whose measured transition widths are of the order of 10^{-4} degrees and whose transitions, as ascertained by measurements of either resistance or susceptibility, appear to be almost completely reversible. From the practical standpoint such specimens may be said to be ideal.

In practice pronounced departures from the ideal behavior are not difficult to produce; indeed, the discovery of the existence of the Meissner effect[7] in 1933 would undoubtedly have occurred much earlier had good homogeneous specimens been available. The early literature is replete with references to the failure of the Silsbee hypothesis[8] in alloys. It is known now that these failures in bulk specimens can generally be traced to rather gross inhomogeneities in the structure. Since this early work, considerable advances have been made in the fields of physical metallurgy and in the technologies of metal purification and preparation. It is only recently, however, that any really serious efforts have been made to delineate the actual mechanisms involved in the departure of practical superconductors from the ideal behavior.

Some experiments of particular pertinence to an understanding of the behavior of superconductors have been carried out by Serin and his coworkers,[9] who have shown that the addition of small amounts of impurity to an initially pure superconductor almost inevitably produces a depression of the critical temperature. In fact, the critical temperature is found to decrease in almost direct proportion to the reduction in electronic mean free path brought about by the added impurities. It is apparent from this work that any sort of impurity gradient or concentration at a particular site in the specimen will lead to a smearing out of the temperature transition of the specimen as a whole. Many of the nonideal characteristics previously observed in alloys, for example, obviously can be traced to the presence of gross inhomogeneities or concentration gradients within the various specimens. That this is undoubtedly the case has been shown by recent work in our laboratory. Simply by taking all precautions to assure specimen homogeneity it has been possible to prepare alloy specimens whose transitions appear to be completely reversible and whose transition widths are measured in fractions of a millidegree. The resistive transition for a typical alloy specimen (an indium mercury alloy) is shown in FIGURE 1.

The availability of extremely homogeneous samples has made possible the observation and study of some of the "fine structure" of the transition characteristics normally obscured in less homogeneous specimens. In particular, a great deal of work has been done recently with tantalum, a material whose transition characteristics are dramatically altered by relatively small impurity concentrations. The behavior of tantalum (and

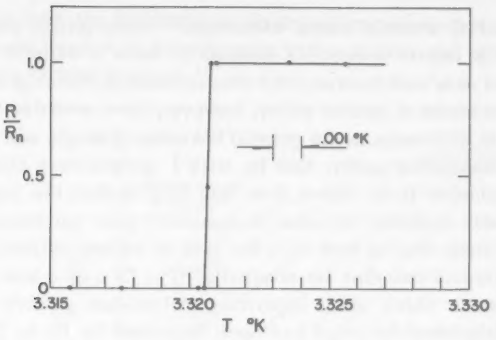

FIGURE 1. The ratio of the measured resistance of an indium mercury alloy to the resistance in the normal state (in the residual resistance range) as a function of the helium bath temperature.

the manner in which the behavior is altered by the presence of impurities) appears to be basically the same as the behavior of most alloys. There are, however, a number of experimental advantages to be realized by using tantalum as model for studying this behavior.

It is helpful in experiments designed to study impurity effects to begin with materials that initially are as pure as can be obtained. Unfortunately, even the purest tantalum available commercially is not very pure. A good criterion for purity is obtained from measurements of the ratio of the resistance of a specimen at room temperature to the resistance at liquid helium temperature. The room temperature resistance is primarily a measure of the ability of the lattice vibrations to scatter the charge carriers. At helium temperature the lattice scattering is several million times smaller than at room temperature and, in practice, the helium temperature resistance can be ascribed almost entirely to impurities or defects in the crystal structure. The ratio of room temperature resistance to that of helium temperature is thus essentially a measure of the ratio of the ideal temperature-dependent scattering to the impurity temperature-independent scattering. The larger this ratio, the purer or more perfect the material.

In commercial high-purity tantalum this ratio, Γ, is typically of the order of 10 to 30. Subsequent purification, generally by vacuum annealing, will raise Γ, and values of about 150 have been reported.[10] Recently J.I. Budnick and D.P. Seraphim have produced in our laboratory tantalum specimens with resistivity ratios greater than ten thousand.[11] Such specimens generally, but not always, are found to have thermodynamically reversible transitions. Some of these very pure samples, on the other hand, exhibit the phenomenon of supercooling and some show hysteresis effects that have not as yet been studied in detail.

Early in this work it was thought that the most ideal specimens would be single crystals of tantalum, and a large number of single crystal specimens

were produced by a strain anneal technique.[12] Some initial measurements with relatively impure specimens seemed to show a definite correlation between grain size and the transition characteristics. Subsequent measurements on specimens of greater purity, however, have revealed that there is no discernible difference in the general behavior of single and polycrystal samples of reasonable purity, that is, with Γ greater than about 100. An obvious conclusion to be drawn from this fact is that the imperfections associated with nonideal behavior in nominally pure specimens are on a dimensional scale that is less than the size of the crystalline grains (the grains in untreated tantalum are nominally 10 to 15 μ on a side).

The manner in which small impurities in tantalum produce departures from the nearly ideal behavior has been described by R. A. Connell and D. P. Seraphim.[13] Briefly, these investigators have shown that the transition may be characterized as though it occurred in two distinct phases. Some typical transitions are shown in FIGURE 2, which contains plots of the specimen resistance as a function of an external longitudinal magnetic field for a particular sample held at a fixed temperature. When a sufficient measuring current is present in the specimen, the transition characteristically consists of a sudden sharp increase in a resistance at a critical field, H_c, followed by a gradual increase of resistance over a considerable range of field. As the measuring current is reduced, the increment of resistance restored in the initial step becomes progressively less and, ultimately, the initial jump in resistance may vanish completely. Independent measurements by Connell and Seraphim have shown that the bulk of the specimen is driven into the normal state by the field H_c independent of the specimen-measuring current. The field H_c is therefore the true critical field of the material. On the other hand, the broad portion of the transition that corresponds to some sort of nonideal behavior is determined not only by the specimen measuring current, but by the temperature at which measurements are made. The lower the temperature, the greater the departure from the ideal behavior.

Connell and Seraphim have pointed out the fact that critical field values have frequently been determined by measuring the field at which 50 per cent of the normal resistance has been restored in the limit of vanishingly small measuring currents. In the light of the behavior shown in FIGURE 2 it is obvious that considerable care must be exercised in determining the true critical field. Connell and Seraphim interpret their results to indicate that at the critical field H_c the bulk of the sample is normal and that small superconducting inclusions in the material are responsible for the fact that the resistance is less than its full normal value. That the inclusions must indeed be small is demonstrated by the fact that they are destroyed by current densities (with regard to the bulk wire size) that would not produce any significant increase in the applied external field. The fact that some of these inclusions are destroyed by fields that are consider-

ably greater than the bulk critical field implies either that they are composed of material that is considerably different from the bulk material or that they are extremely small.[14]

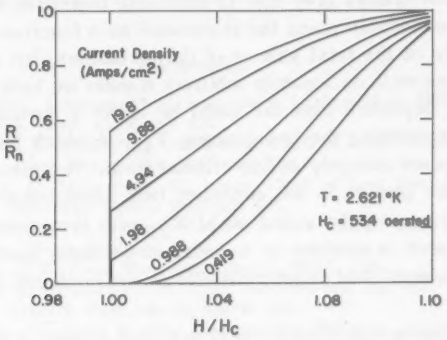

FIGURE 2. The ratio of measured to normal resistance for a tantalum wire as a function of the applied longitudinal magnetic field normalized to the bulk critical field H_c. Curves are shown for measurements made at a number of different measuring current densities. These data were obtained by R. A. Connell and D. P. Seraphim.[13]

Some recent experiments[15] on tantalum indicate that the impurity concentration necessary to produce pronounced departure from nearly ideal behavior is quite small. This was demonstrated by loading initially pure tantalum specimens with nitrogen, which is known to go into solution.[16] The presence of small amounts of nitrogen introduced by allowing a tantalum wire heated nearly to its melting point to come to equilibrium with a surrounding nitrogen atmosphere will produce a marked enhancement of the nonideal behavior. The departure from ideal behavior is a somewhat dif-

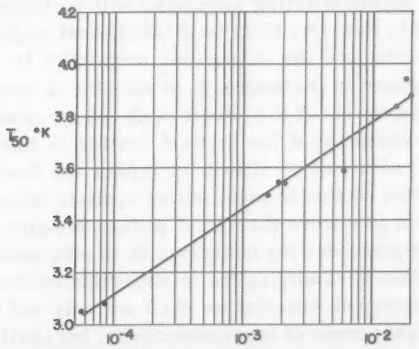

FIGURE 3. The variation of T_{50} (defined in the text) as a function of the atomic percentage of nitrogen present in a series of tantalum wires.

ficult parameter to characterize in a quantitative manner. In general, the superconducting inclusions in a given specimen are more pronounced the greater the impurity content, the lower the measuring current, and the lower the measuring temperature. The same fraction of inclusions, however, does not always give rise to the same transition broadening. This fact is understandable since the resistance as a function of field will depend not only on the total volume of the inclusions, but upon their shape and number as well. In a purely arbitrary manner we have chosen to characterize the departure from the ideal by using a preselected measuring current and specifying the temperature, T_{50}, at which just half of the resistance appears abruptly at the critical field. The greater the temperature, T_{50}, the greater is the departure from ideal behavior. FIGURE 3 shows, for example, the variation of T_{50} with the atomic percentage of nitrogen present in solution in a series of tantalum specimens. It is immediately apparent that measurable effects are produced by small amounts of gas.

It is now known that it is not only the total amount of gas present in the specimen that determines how significantly it departs from the ideal, but the deposition or concentration of the gas as well. The nature of the actual mechanism that allows a superconducting matrix to form and persist in a field greater than critical is currently under study by D. P. Seraphim and others in our laboratory. Experiments in which nitrogen-contaminated tantalum specimens have been held at temperatures that permit a slight diffusion of the gas within the specimen show that this treatment considerably enchances the formation of superconducting inclusions. Moreover, there is a saturation of the effect after a length of time. A possible, but by no means established, mechanism to explain this behavior is the migration of nitrogen atoms in the stress field of dislocations present in the specimen. The clustering of nitrogen atoms about dislocations and the formation of a Cottrell "atmosphere"[17] might provide the nucleation centers at which superconducting inclusions will be formed at low temperature. There are, however, other mechanisms that might also produce the observed behavior and the responsible mechanism is still in doubt.

Work on this problem is continuing. It is possible to vary the structure by straining; measurements of the effects produced by strain are currently under study. Measurements of the internal friction in tantalum are also being considered as a tool to illuminate further the basic mechanisms involved. In addition, studies of supercooling in dilute alloys are being attempted in an effort to resolve the role of surface energies in determining the formation of superconducting inclusions in an otherwise normal specimen. It is hoped that by clarifying the relationships between microscopic structure and macroscopic behavior we shall not only add to the store of knowledge of the phenomena of superconductivity, but shall simultaneously answer a number of questions pertaining to the desired characteristics of materials for use in practical computer applications.

Acknowledgment

A substantial part of the work reported in this paper was both conceived and carried out by J. I. Budnick, R. A. Connell, and D. P. Seraphim. I am indebted to these co-workers for being allowed to summarize their results in order to present a coherent picture of the work in progress.

References

1. ONNES, H. K. 1911. Commun. Phys. Lab. Univ. Leiden. Nos. **119b**; **120b**; **122b**.
2. BUCK, D. A. 1956. Proc. I.R.E. **44**: 482,
3. BUCKINGHAM, M. J. 1958. Proc. 5th Intern. Conf. of Low Temperature Phys. & Chem. :229. Univ. Wis. Press, Madison, Wis.
4. CRITTENDEN, E. C. 1958. Proc. 5th Intern. Conf. of Low Temperature Phys. & Chem. :232. Univ. Wis. Press, Madison, Wis.
5. CROWE, J. W. 1958. Proc. 5th Intern. Conf. of Low Temperature Phys. & Chem. :238, Univ. Wis. Press, Madison, Wis.
6. PIPPARD, A. B. 1950. Proc. Roy. Soc. London. **203A**: 210.
7. MEISSNER, W. & R. OCHSENFELD. 1933. Naturwissen. **21**: 787.
8. SILSBEE, F. B. 1916. J. Wash. Acad. Sci. **6**: 597.
9. SERIN, B. 1955. Progress in Low Temperature Physics. A Review. 1:138. C. J. Gorter, Ed. North Holland Publ. Co. Amsterdam, Netherlands.
10. THOMAS, H. 1952. Phys. Rev. **88**: 325.
11. BUDNICK, J. I. , W. B. ITTNER & D. P. SERAPHIM, 1958. 6th Intern. Conf. of Low Temperature Phys. & Chem. Leiden, Netherlands.
12. SERAPHIM, D. P., W. B. ITTNER & J. L. BUDNICK. To be published.
13. CONNELL, R. A. & D. P. SERAPHIM. 1958. A.P.S. Chicago, Ill. To be published.
14. LONDON, F. 1950. Superfluids. :130. Wiley & Sons, New York, N.Y.
15. ITTNER, W. B., III & J. MARCHAND. Submitted to the Phys. Rev.
16. ANDREWS, M. R. 1932. J. Am. Chem. Soc. **54**: 1845.
17. COTTRELL, A. H. 1949. Progr. Metal Phys. **1**: 77.

DIVISION OF PSYCHOLOGY

EXPLORATORY STUDIES OF DEPENDENCY*

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Dependency is reinforced from earliest infancy and throughout the total life cycle of most people in most societies. It is difficult to isolate dependency for study because it enters into many phases of interpersonal experiences, as for instance, love and hate, domination and submission, conformity and rebellion, and cooperation and competition. Cultural pressures and negative personal experiences often produce conflicts that lead to inhibition, disguise, and inconsistency in the overt expression of motivation and other aspects of dependency. These are sources of difficulty for the measurement of dependency. However, if we are to arrive at a comprehensive theoretical formulation, we must construct adequate measures for these varied manifestations of dependency, the conditions that affect their interaction, and their relationships to other psychological variables.

A review of the recent literature on research in dependency reveals considerable agreement on the choice of behaviors investigated in several studies and on the choice of conditions expected to reinforce these behaviors. However, discrepancies among findings from various studies raise serious questions for further research on dependency. This paper bears on two areas in which discrepancies exist. There is disagreement on: (1) amount of homogeneity found among different manifestations of dependency within a child,[2,10,14,19,24] and (2) the antecedents of dependency. With regard to the latter, frustration in the form of early absence of mothering has been reported to relate to a decrease in the expression of dependency in some studies,[21,25] to an increase in another,[12] and to either "apathy" or increased dependency or to both in still others.[8,9,15] Frustrations due to parental handling of nursing in infancy were found to correlate with heightened dependency by one group of investigators,[18] but not by others.[19,20,22] There is more agreement and

*This is a summary of a paper, illustrated with slides, which was presented at a meeting of the Division on February 16, 1959. Some of the studies discussed in this article are part of a research project entitled "A Study of Fears as Related to Aggression and Dependency in Early Childhood," which is being supported by Grant M-849 (C1,2,3) from the National Institute of Mental Health, Public Health Service, Bethesda, Md., and carried out in collaboration with Ann W. Haeberle.

The Division of Instrumentation held a meeting on February 17, 1959, at which Richard W. Lawton of the General Electric Company, Philadelphia, Pa., presented a paper on "Instrumentation Problems Relating to Man and Space Flight: Biomedical Aspects of Telemetry." This paper will be published in the *Annals* of the Academy.

more conclusiveness in findings of increased dependency due to lowered or inconsistent reponsiveness by adults to dependency requests from children.[11,16,19,22]

Better control of certain factors would probably reduce disagreement in findings or make such disagreements more meaningful. One source of disagreement may arise from differences in the definition and measurement of dependency. For example, some investigators study dependency without defining it, others define it as a motive or secondary drive, and one recent investigator defines it as an "inbuilt instinctual need."[7] One example of differences in measurement is the use of bipolar dimensions with dependency at one end and independence at the other in some studies, while other studies have used a continuum from high to low dependency.[1,2] A second source of variations in findings about dependency may stem from a lack of repeated measurements of subjects in some studies. A third source of disagreement derives from the fact that subjects used in various studies differed with respect to age, emotional adjustment, family, and cultural background. Variations in factors such as these may be expected to affect dependency sufficiently to account for differences in research findings. Finally, the choice of situations in which dependency has been studied has varied from orphanages,[12,21,25] clinics,[2,17] experimental situations,[3,11,13] normal school nurseries,[1,10,14] and home environments[16,19] to broad cultural settings in anthropological research.[23] Findings reported from such different situations will gain in value if attempts are made to control characteristics of situations that may affect dependency in specific predictable ways.

This paper, which is based on continued and intensive studies of dependency over a period of five years, will concentrate on two specific aspects of research in dependency: (1) definition and measurement of dependency; (2) a measure of dependency conflict; and (3) dependency and situational stress.

Subjects

The studies to be reported were carried out on 74 children (45 girls and 29 boys) who were 2½ to 6 years of age and coming from middle-class homes. Most of these children were emotionally disturbed. All attended the nurseries of the Child Development Center[2] (for remainder of procedure, see *Note on Procedure,* below).

Definition and Measurement of Dependency

The definition of dependency that follows was based on an analysis of the parent-child interaction in infancy. The human infant is helpless and cannot survive without intervention of the adult. The parent helps or provides for the infant, attends to him, and is in physical contact with him. Through repeated experiences these types of parental behavior become associated with gratification. When a child seeks attention and physical

contact apart from gratification of other needs, dependency is no longer simply a physical necessity, but rather a psychological motive.

The basic measures of overt dependent striving consisted of 5 components defined as a child's seeking; help, physical contact with and nearness to others, attention, and recognition. Each of the measures was obtained from 2 independent observers: nursery teachers who spent over 20 hours a week with the children. These observations were repeated 4 times annually. On the average, a child was included in the study for a period of 2 years. This provided us with large samples of behavior and stability of measures. Observers were trained to base their observations on important situations of a nursery day and on the child's interactions with all adults and all children. This assured a representative sampling of situations and of people toward whom the dependency responses were made. A third instruction, to include the effect of the child's behavior on the observer, has important implications for the meaning of these measures (this has been discussed in greater detail in an earlier study[4]).

The first task was to determine how well the specific measures of dependency were intercorrelated. TABLE 1 presents the outcome of an analysis based on approximately 12,000 measures of dependency obtained from 74 children over a period of 5 years.* As may be seen from an inspection of the coefficients in the upper left and lower right triangles of TABLE 1, the 5 measures of dependency on adults, as well as the 5 measures of dependency on children, were all substantially intercorrelated ($\bar{r} = 0.63$ for each cluster). One may therefore conclude that these specific measures of dependency on adults and on children are indicators of a more generalized dependency motive. However, the interrelationship between measures of dependency on adults and on children is much lower ($r = 0.30$), which means that there is less homogeneity between the 2 areas than within each (TABLE 1). This indicates some generalization of dependency on adults and on children, but it makes their summation into one measure questionable.†

Measures of independence, or autonomous achievement striving, were separately defined. This definition was formulated by making an analysis of exploratory behavior in the young child.[1,2] The specific measures of autonomous achievement striving were: trying to initiate activities; to overcome obstacles; to complete activities; to do things by oneself; and to derive satisfaction from work. Deriving satisfaction from work was operationally defined.[2]

*A similar analysis based on the 2½ years of this study was reported elsewhere.[2]
†To reduce complexity of presentation, any subsequent mention of dependency (scores), dependency motivation, or dependent striving will refer to average scores of these 5 measures of dependency on adults. Throughout this report, in all analyses in which relationships between dependency and other measures were tested, these average scores constituted the measure of dependency (with the exception of TABLE 5).

TABLE 1

PRODUCT-MOMENT COEFFICIENTS OF CORRELATION (r) WITHIN AND BETWEEN FIVE MEASURES OF DEPENDENCY ON ADULTS AND FIVE MEASURES OF DEPENDENCY ON CHILDREN

Based on 74 Children Ranging From 2½ to 6 Years of Age

Scales	1	2	3	4	5	6	7	8	9
Dependency on adults			(N=74)*						
1. Seeking help									
2. Seeking recognition	0.42								
3. Seeking physical contact	0.58	0.41							
4. Seeking attention	0.72	0.55	0.69						
5. Seeking physical nearness	0.66	0.57	0.79	0.77					
Dependency on children			(N=66)*					(N=66)*	
6. Seeking help	0.35	0.26	0.20	0.21	0.11				
7. Seeking recognition	0.15	0.50	0.18	0.27	0.25	0.49			
8. Seeking physical contact	0.27	0.37	0.34	0.39	0.32	0.58	0.61		
9. Seeking attention	0.31	0.48	0.24	0.54	0.40	0.57	0.73	0.58	
10. Seeking physical nearness	0.06	0.39	0.24	0.37	0.35	0.44	0.77	0.62	0.79

$N = 74$, $p < 0.01$ for $r = 0.30$, $p < 0.05$ for $r = 0.23$
$N = 66$, $p < 0.01$ for $r = 0.32$, $p < 0.05$ for $r = 0.25$

*Measures for dependency on children were available for only 66 of the subjects.

The coefficients in the lower right-hand triangle of TABLE 5 show that measures of autonomous achievement striving were sufficiently intercorrelated positively ($\bar{r} = 0.51$) to be considered as indicators of a generalized autonomous achievement motive. The interrelationships between dependency on adults and autonomy, as can be seen in TABLE 2, were for the most part negative, but sufficiently low (average $r = -0.17$) to assure two sets of measures that do not constitute a bipolar continuum. The same relationships ($\bar{r} = -0.16$) were found between measures of dependency on children and of autonomous achievement striving (TABLE 3).

TABLE 2

PRODUCT-MOMENT COEFFICIENTS OF CORRELATION (r) WITHIN AND BETWEEN FIVE MEASURES OF DEPENDENCY ON ADULTS AND FIVE MEASURES OF AUTONOMOUS ACHIEVEMENT STRIVING

Based on 74 Children Ranging From 2½ to 6 Years of Age

Scales	1	2	3	4	5	6	7	8	9
Dependency on adults									
1. Seeking help									
2. Seeking recognition	0.42								
3. Seeking physical contact	0.58	0.41							
4. Seeking attention	0.72	0.55	0.69						
5. Seeking physical nearness	0.66	0.57	0.79	0.77					
Achievement striving									
6. Deriving satisfaction from work	0.16	0.02	-0.04	-0.22	-0.04				
7. Trying to do routines by oneself	-0.54	-0.04	-0.27	-0.41	-0.19	0.38			
8. Trying to overcome obstacles	-0.47	-0.15	-0.16	-0.21	-0.30	0.55	0.40		
9. Trying to initiate activities	-0.25	-0.10	-0.12	-0.14	-0.22	0.42	0.17	0.64	
10. Trying to complete activities	-0.14	-0.03	0.03	-0.12	0.03	0.85	0.40	0.57	0.47

$N = 74$, $p < 0.01$ for $r = 0.30$, $p < 0.05$ for $r = 0.23$

A Measure of Dependency Conflict

The fact that those measures were constructed in this way made it possible to deal with the balance between dependent and autonomous striving in a child and thereby derive a separate measure: dependency conflict. As the child develops, he must gradually relinquish dependency and assume more antonomy or independence. This process of growth can involve considerable conflict for the child, since the child may be motivated equally to behave dependently and autonomously. This has actually been tested as a hypothesis in a series of experimental studies in which it was found that children with greater similarity of dependency and

autonomy scores, that is, higher dependency conflict, were more inhibited and inconsistent in their expression of dependent responses.[5]

The importance and fruitfulness of this measure of dependency conflict can be seen by inspection of TABLE 4. This table presents findings from several studies in which hypothesized relationships between dependency and other measures were tested. Comparison of columns 2 and 3 in TABLE 4 shows that in the majority of instances the predicted relationships were strongly confirmed in children with low dependency conflict and were not found in children with high conflict.* In the low conflict group, children with higher dependency scores were, as hypothesized, consistently higher in manifesting infantile and unsocialized behaviors related to feeding and toileting,[2] in being visually oriented toward (looking at) adults and adult-child interactions,[6] and in accepting help whenever it was offered to them. Thus, strength of dependency motivation has good predictive value in children who are unconflicted about their dependency, but not in children with high dependency conflict. The last finding in TABLE 4 has particular importance. This dimension was specially constructed to measure dependency motivation. It extended from constantly seeking help to seeking help only when such help was realistically required. A substantial correlation was found in the total group between the dependency scales and this new measure. Moreover, this correlation was unaffected by conflict and remained stable in both the low and high conflict groups. This was therefore additional evidence that the striking differences between high and low conflict groups in other respects cannot be attributed to a difference between the two groups in strength of dependency motivation alone.

When taken as a separate measure in one study, dependency conflict related to certain variables more consistently and differently than did mere strength of dependency motivation. For instance, children with high dependency conflict gave consistently more evidence of behavior problems (toileting problems, defiant and compulsive behavior), which are usually associated with frustrations experienced around toilet training.[5] It is not unlikely that some studies[18,22] failed to find relationships between socialization in toileting and dependency because they did not employ measures of dependency conflict. The use of such direct measures of dependency conflict may well lead to clarification in the study of origins of dependency and the conditions that reinforce it.

I do not think that the foregoing is more than a beginning in studying dependency conflict as a separate variable, although these separate measures of motivational strength and of conflict have already opened up new possibilities of refinement in studying dependency.

*The method of selecting these groups, described elsewhere,[2] assured an equal range and an equal average value of dependency scores in these two groups.

TABLE 3
PRODUCT-MOMENT COEFFICIENTS OF CORRELATION (r) BETWEEN FIVE MEASURES OF DEPENDENCY ON CHILDREN AND FIVE MEASURES OF AUTONOMOUS ACHIEVEMENT STRIVING

Based on 66 Children From 2½ to 6 Years of Age

Achievement striving	Help	Recognition	Physical contact	Attention	Physical nearness
	1	*2*	*3*	*4*	*5*
6. Deriving satisfaction from work	-0.34	-0.30	-0.26	-0.18	-0.21
7. Trying to do routines by oneself	-0.19	-0.16	-0.32	-0.05	-0.02
8. Trying to overcome obstacles	-0.36	-0.22	-0.15	0.04	-0.04
9. Trying to initiate activities	-0.17	-0.09	-0.02	0.01	-0.03
10. Trying to complete activities	-0.31	-0.18	-0.22	-0.08	-0.09

N = 66, $p < 0.01$ for $r = 0.32$, $p < 0.05$ for $r = 0.25$

TABLE 4
PRODUCT-MOMENT COEFFICIENTS OF CORRELATION (r) BETWEEN DEPENDENCY AND OTHER MEASURES

Based on Children with High and Low (Dependency-Autonomy) Conflict

	Total group	Low conflict	High conflict
Socialization	(N = 49)	(N = 23)	(N = 23)
Oral manifestations	0.30*	0.63†	0.18
Anal manifestations	0.15	0.45*	0.04
Perceptual orientations‡	(N = 29)	(N = 8)	(N = 11)
Adult orientation	0.50†	0.83†	0.24
Adult-child orientations	0.27	0.74*	-0.05
Object relations	(N = 71)	(N = 18)	(N = 18)
Acceptance-rejection of help	0.31†	0.73†	0.23
Request for help regardless of need	0.59†	0.49*	0.58*

* $p \leq 0.05$, † $p \leq 0.01$

‡ Spearman Rank Correlation Coefficients (Rho) were used in this study.

Dependency and Situational Stress

Let me now turn to the next step, that of examining situations in which dependency is studied. The particular situational characteristics investigated were varying conditions of stress. As its definition indicated, the roots of dependency motivation lie in the infant's inability to reduce painful stimulation by himself and the necessity for the infant to rely on others for relief. Once dependency motivation has developed, the parent's attention and presence become synonymous with obtaining relief. Subsequently, a threat of losing the attention and presence of a parental figure becomes synonymous with being in danger of not getting relief from pain. Thus, a fear or anxiety mechanism that becomes an integral part of dependency is set in motion. (This may in part explain why many young children respond with stress reactions to separation from the parent.) This mechanism persists into later phases of development, but its presence becomes less visible and the sequence is shortened to: dependency deprivation instigates internal dependency responses that lead to a heightened level of dependency motivation. Although the fear mechanism becomes less visible, its continued presence in dependency motivation is an important reason why dependency deprivation or signals of such deprivation produce stress reactions and a heightened level of dependency motivation. (Conversely, anticipation of dependency gratification produces reactions of relief and pleasure.) To what extent such deprivation will increase a child's dependency responses in a given situation will be a function of his initial dependency level. The more dependent a child, the more sensitive will he be to such deprivation. This formulation explains why we consider situations in which an adult does not offer, or withholds, dependency gratification as a stress situation for a child. It also offers a theoretical explanation as to why deprivation in the case of this motivation or secondary drive may lead to a heightening of dependency responses. Finally, inconsistent dependency gratification by a parent may heighten the stressful effect of withholding, partly because it interferes with the child's discrimination as to whether to react dependently.

I have selected several situations from our studies that permitted us to test two hypotheses: (1) dependent behavior will be higher in dependency stress situations then in comparable nonstress situations; and (2) the higher a child's initial dependency, the greater will be the increase of his dependency behavior in the stress situation.

A first test of these hypotheses was carried out on data from the perceptual orientation study. It made it possible to test whether children will look more often at the adult in a dependency stress situation (free play, in which the adult is generally less available to any one child) than in other nursery situations (organized work, lunch). As can be seen from TABLE 5 (Rows 1 and 2), Hypothesis 1 was clearly confirmed. Children were more adult- and adult-child-oriented in the stress situation.

Hypothesis 2 was also confirmed. Initial dependency scores correlated significantly with the amount of increased looking at adults and at adult-child interactions in the dependency stress situations (rho = 0.46 and 0.45, $N = 29$, $p < 0.01$).

The second test was carried out on data obtained from psychotherapy situations. Dependency stress was controlled by selecting those sessions that were characterized by separation experiences with the therapist. The criteria of separation were the therapist's canceling, postponing, or being late to a session. Nonstress situations were those in which there was no evidence of such separation experiences. In this study Hypothesis 1 was not confirmed. Although the majority of children changed in the direction of requesting more help in the separation sessions, the magnitude of this change in the total group was not large enough to be statistically significant (Row 3 in TABLE 5). However, Hypothesis 2 was clearly confirmed. Initial dependency scores correlated significantly with the magnitude of increase of dependency responses in the stress situations (rho = 0.64, $N = 14$, $p < 0.01$).

TABLE 5
AVERAGE INCREASE ($\bar{X}$) OF DEPENDENT BEHAVIOR FROM NONSTRESS TO STRESS SITUATIONS

Situations and behaviors	N	$\bar{X}$	t*	p*
Nursery				
Perceptual orientations				
Adult orientation	29	2.37	2.724	<0.01
Adult-child orientation	29	1.68	2.400	<0.05
Psychotherapy				
Request for help	14	0.03	0.600	0.30

*d.f.-N = 1.

These findings lend some support to Hypothesis 1. Dependency stress in the form of reduced and inconsistent availability of the adult heightened dependency manifestations in children. The results are consistent with studies that found frustration, lower availability, and inconsistent gratification as antecedents of increased dependency.[11,16,19,22] Hypothesis 2 was clearly confirmed by the findings. The degree of increased dependency behavior in the stress situation varied as a function of a child's initial dependency score.

The fact that I found dependency to be more activated by stress led me to expect that *(a)* various aspects of dependency will be more clearly expressed in, and *(b)* dependency will interact more systematically with

other behaviors in more stressful situations. To investigate (*a*), a number of relationships were tested between motivational and cognitive aspects of dependency in the stress and nonstress situations described previously. In TABLE 6 (Part I, columns 2 and 3), motivational and certain cognitive aspects of dependency as hypothesized, correlated substantially in the stress situations. Specifically, the more dependent a child was, the more he was perceptually oriented toward adults, and the more he saw adults as powerful and himself as helpless. No such relationships were found in the nonstress situations. To investigate (*b*), relationships were tested between dependency and several "anxious" manifestations of aggression. As may be seen from TABLE 6 (Part II, columns 2 and 3), dependency, as hypothesized, correlated substantially with such aggression in the stress situation, but only negligibly in the nonstress situations.

The last parts (IA and IIA) of TABLE 6 reveal a very different picture. Seeing the adult as reasonably helpful and oneself as age-adequate, which were practically the opposite of seeing the adult as powerful and oneself as helpless, correlated negatively with dependency, but only in the nonstress situation (see Part IA, columns 2 and 3, in TABLE 6).

TABLE 6

SPEARMAN RANK COEFFICIENTS OF CORRELATION (RHO) BETWEEN DEPENDENCY AND OTHER MEASURES OBTAINED IN STRESS AND NONSTRESS SITUATIONS

Part		*All*	*Stress*	*Nonstress*
	Perceptual orientations	(N = 29)	(N = 29)	(N = 29)
I	1. Adult orientation	0.50†	0.65†	0.27
	2. Adult-child orientation	0.27	0.61†	0.05
	Psychotherapy	(N = 16)	(N = 10)‡	(N = 14)‡
	3. Sees adult as powerful	0.36	0.67*	0.06
	4. Sees self as helpless	0.49*	0.61*	0.09
II	5. Destructive aggression	0.47*	0.57*	0.05
	6. Mounting aggression	0.32	0.66*	0.12
	7. Ambivalent aggression	0.07	0.73*	-0.46
IA	3a. Sees adult as reasonably helpful	-0.22	0	-0.75†
	4a. Sees self as age-adequate	-0.03	0.02	-0.48*
IIA	5a. Assertive aggression	-0.52*	-0.43	-0.53*

* $p \leq 0.05$, † $p \leq 0.01$

‡ Subjects for whom there was insufficient evidence to apply our criteria of stress and nonstress were not included

A different picture also emerged with respect to assertive aggression which, in contrast to destructive aggression, correlated negatively with dependency. This corroborated similar earlier findings that have been discussed in greater detail elsewhere.[3] However, the present finding amplified the earlier ones, since it was now discovered that dependency not only relates, as previously, in opposite directions to these two types of aggression, but its relationship to destructive aggression is very much affected by dependency stress, whereas its relationship to assertive aggression is not. These findings demonstrate that certain variations of dependency emerge more clearly in more stressful situations and others more clearly in less stressful situations. Moreover, when stress was not controlled, the over-all findings were less systematic and less conclusive (see column 1 in TABLE 6).

Finally, the limits of this report do not permit me to discuss findings from our current investigation of the effect of stress on dependency conflict. I can only indicate here that the expressions of dependency conflict are also affected by situational stress. Furthermore, initial degree of dependency conflict seems to be an important factor in a child's differential reaction to stress.

In summary, this report dealt with two problems in our research on dependency of children. The first problem was that of definition and measurement. The definitions of dependency and of autonomous striving formulated made it possible to obtain separate measures of dependency motivation and dependency conflict and to study the interaction between the two. Findings from several studies were presented to illustrate the fruitfulness of making this distinction. Second, the importance of defining and controlling the situation in which dependency variations are studied was investigated. The specific investigations dealt with the effect of situational stress on manifestations of dependency. Findings were presented that lent support to the hypothesis that stress leads to an increase of dependency behavior and that this increase is a function of the initial strength of a child's dependent striving. Finally, relationships between motivation and cognitive aspects of dependency emerged clearly only when stress was controlled. Variations in stress also affected and thereby clarified certain relationships between dependency and aggression.

Note on procedure. This report cuts across a series of studies. Detailed procedures of some of these studies have been presented elsewhere.[1-6]

Measures of dependency and of autonomous achievement striving were obtained in terms of frequency and persistence of behavior rated on seven-point scales. Reliabilities (rho) of observer pairs for these measures ranged from 0.53 to 0.99, with a median of 0.82. Only reliable measures were used as data.[2]

Sixteen oral behavior manifestations, for example, biting, sucking, and overeating, and nine anal behavior manifestations, for example, bowel control, messing and avoiding messing, were obtained from records kept for such information. Percentage agreement by coders ranged from 0.50 to 1.00, with a median of 0.83.[2]

Perceptual orientations, that is, looking at adults and at adult-child interactions, were studied by direct observation of children's eye movements in ten 2-minute time samples in 3 selected situations. Reliability (r) of observers ranged from 0.75 to 0.92, with a median of 0.83.[6]

Measures of (1) accepting and rejecting help and (2) requests for help (from constantly to only when needed) were obtained from nursery records. Reliabilities (r) were 0.79 and 0.61.

The following measures were obtained from the psychotherapy study. (1) Dependency: initiating requests for help, seeing self as helpless or as age-adequate, seeing adult as powerful or as reasonably helpful; and (2) Aggression: destructive (aggressive acts involving injury and physical damage as the goal response), mounting (when one aggressive act leads to another), ambivalent (when the child assumes the role of both aggressor and victim while carrying out an aggressive act), and instrumental (when any injury or damage was incidental to a nonaggressive goal). These measures were obtained from interviews with therapists following each of 8 therapy sessions of every one of 16 children. Percentage agreement among coders ranged from 0.63 to 0.96, with a median of 0.87.

Statistical significance of findings resulting from tests of hypothesized relationships and presented in TABLES 4 to 6 and by 3 coefficients of correlation in the text were determined by one-tailed tests and reported for results that were in the predicted direction.

References

1. BELLER, E. K. 1955. Dependency and independence in young children. J. Genet. Psychol. 87: 25-35.
2. BELLER, E. K. 1957. Dependency and autonomous achievement striving related to orality and anality in early childhood. Child Develop. 28: 287-315.
3. BELLER, E. K. 1957. Dependency, socialization and emotional disturbance in early childhood. Presented at the Symposium of Dependency in Personality Development. 65th Ann. Meetings Am. Psychol. Assoc. (Aug. 31).
4. BELLER, E. K. Direct and inferential observations in the study of children. Am. J. Orthopsychiat. In press.
5. BELLER, E. K. & A. W. HAEBERLE. 1958. Studies in dependency and aggression. Presented at the 35th Ann. Meetings Am. Orthopsychiat. Assoc.
6. BELLER, E. K. 1958. A study of dependency and perceptual orientation. Am. Psychologist. Abstr. 13: 347.
7. BOWLBY, J. 1958. The nature of the child's tie to his mother. Intern. J. Psa. 39(5): 350-373.
8. COX, F. N. 1953. The origins of the dependency drive. Australian J. Psychol. 5: 64-73.

9. FREUD, A. & D. BURLINGHAM. 1948. Infants Without Families. Intern. Universities Press. New York, N.Y.
10. GEWIRTZ, J. L. 1956. A factor analysis of some attention-seeking behaviors in young children. Child Develop. **27**: 17-36.
11. GEWIRTZ, J. L., D. M. BAER & C. H. ROTH. 1958. A note on the "similar" effect of low social availability of an adult and brief social deprivation on young children's behavior. Child Develop. **29**: 149-152.
12. GOLDFARB, W. 1953. The effects of early institutional care on adolescent personality. J. Exptl. Educ. **12**: 106-129.
13. HARTUP, W. D. 1955. Nurturance and nurturance withdrawal in relation to the dependency behavior of preschool children. Harvard Educ. Rev. Abstr. **25**: 264-266.
14. HEATHERS, G. 1955. Emotional dependence and independence in nursery school play. J. Genet. Psychol. **87**: 37-57.
15. IRVINE, E. E. 1952. Observations on the aims and methods of child rearing in communal settlements in Israel. Human Relations. **5**: 247-275.
16. LAFORE, G. G. 1945. Practices of parents in dealing with preschool children. Child Developm. Monogr. No. **31**. Bureau of Publ. Teachers College, Columbia Univ. New York, N. Y.
17. LEVY, D. M. 1943. Maternal Overprotection. Columbia Univ. Press. New York, N. Y.
18. SEARS, R. R. *et al*. 1953. Some child-rearing antecedents of aggression and dependency in young children. Genet. Psychol. Monogr. **47**: 135-234.
19. SEARS, R. R., E. E. MACCOBY & H. LEVIN. 1957. Patterns of Child Rearing. Row, Peterson & Co. Evanston, Ill.
20. SEWELL, W. & P. MUSSEN. 1952. Effects of feeding, weaning, and scheduling procedures on childhood adjustment and the formation of oral symptoms. Child Develop. **23**: 185-191.
21. SPITZ, R. A. & K. M. WOLF. 1946. Anaclitic depression: an inquiry into the genesis of psychiatric conditions in early childhood. Psychoanalytic Stud. Child. **2**: 313-342.
22. STENDLER, C. B. 1954. Possible causes of overdependency in young children. Child Develop. **25**(2): 125-146.
23. WHITING, J. W. M. & I. L. CHILD. 1953. Child Training and Personality. Yale Univ. Press. New Haven, Conn.
24. WITTENBORN, J. R. *et al*. 1956. A study of the adopted child. I. Interviews as a source of scores for children and their homes. Psychol. Monogr. **70** (1).
25. WITTENBORN, J. R. & B. MYERS. 1957. The Placement of Adoptive Children. Thomas. Springfield, Ill.

THE NEW YORK ACADEMY OF SCIENCES

DIVISION OF ENGINEERING

STRESS WAVES IN DISSIPATIVE MEDIA*

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The Media Characteristics

Media that respond to dynamic stresses independently of the strain rate can be fully described by a stress-strain diagram. Stress-wave phenomena in elastic and elastoplastic materials have been discussed in the literature.[1] In this paper some "nonclassic" materials are considered.

A first group of materials is characterized by stress-strain diagrams, as shown in FIGURE 1*a* to *d*, which exhibit a classic form of response up to a critical strain e_c. In particular, this portion of the stress-strain diagram is linear elastic in *a*, elastoplastic in *b*, rigid plastic in *c*, and fully plastic in *d*. When each of these materials attains the critical strain e_c, it becomes locked, or compacted, and behaves thereafter as a rigid body as indicated by the vertical line of the stress-strain diagram at e_c. The static response of a locking medium has recently been explored by W. Prager.[2]

A second group of materials is characterized by a linear stress-strain diagram during initial loading, as shown in FIGURE 2*a* and *b*. However, locking or compaction is manifested during unloading, that is, under a decreasing stress. If complete locking occurs, the compaction is permanent, and the compacted portion of the medium becomes a rigid mass as indicated by the vertical unloading branch of the stress-strain curve in FIGURE 2*a*. If the compaction is incomplete, the compacted portion responds linearly during unloading, as shown by the inclined unloading branch of the stress-strain diagram in FIGURE 2*b*. The elastic modulus during the unloading is larger than that for the initial loading, as indicated by the steeper slope of the unloading branch of the stress-strain curve. This behavior can also be interpreted as a strain-hardening effect in a material that yields initially at zero stress.

Both groups of materials have the property of locking or compacting under either a particular stress intensity or a particular type of loading. This is also characteristic of granular soils. The compaction may occur suddenly when a critical stress intensity is reached and can be interpreted as a sudden rearrangement of grains from a loose to a dense state, resulting in large strains and large density or void ratio changes. This

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behavior is approximated by the stress-strain diagrams of the first group of media (FIGURE 1).

Compaction may also occur gradually as the load increases, corresponding to a continuous rearrangement of grains. This type of compaction is approximated by the stress-strain diagrams of the media of the second group (FIGURE 2).

The Propagation of Stress Waves

The pressures generated by high-energy explosions can be sufficient to

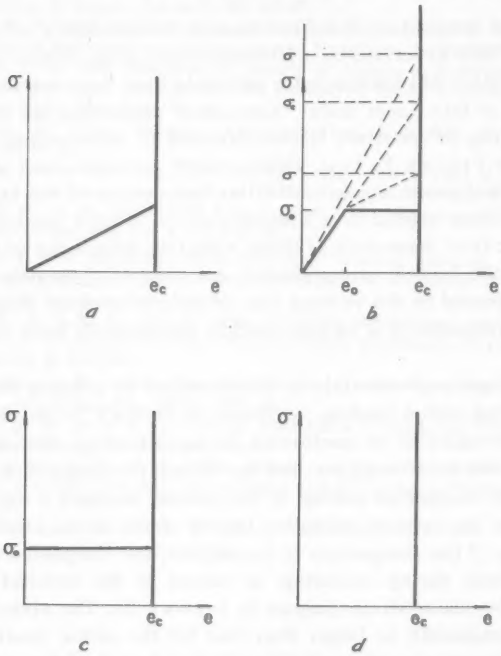

FIGURE 1. Stress-strain diagrams, group I.

produce compaction phenomena beneath a large area of the ground surface. It is well known that such blasts also produce seismic waves of essentially elastic character that are detectable at great distances. In the immediate vincinity of the blast, however, nonelastic phenomena are predominant. There is a rapid penetration of a high-intensity pressure wave that compacts the soil as it propagates. In the discussion below, the existence of such "compaction fronts" or "locking fronts" is established, and the associated wave propagation equations are given. Since the compaction process is inherently dissipative, the compaction front becomes stationary after a cer-

tain length of time, resulting in a compacted layer in which irrecoverable strains exist.

Consider a semi-infinite medium extending from $y = 0$ to $y = \infty$, described by the stress-strain curve of FIGURE 1*b*. A pressure pulse $p(t)$ is applied to the entire surface of the medium consisting of a sudden rise to a peak pressure p_o and then a gradual decay to zero, as is typical of blast waves.

If $o < p_o < \sigma_o$, an elastic plane compression wave will be propagated in the positive y direction at the velocity c_o given by

$$c_o = \sqrt{\frac{\sigma_o}{e_o \rho_l}} \tag{1}$$

where σ_o is the stress corresponding to the maximum elastic strain e_o, FIGURE 1*b*, and $\dot{\rho}$ is the initial density of the material.

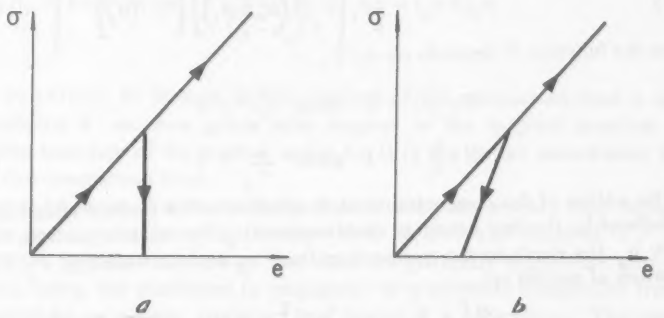

FIGURE 2. Stress-strain diagrams, group II.

If $p_o > \sigma_o$, a compaction wave will be produced and the compaction front at a depth z will advance with the velocity $\dot{z}$. If, in particular, the initial pressure ρ_o is in the range:

$$\sigma_o < p_o < p_{cr} \tag{2}$$

where

$$p_{cr} = \frac{e_c}{e_o}\ \sigma_o \tag{3}$$

and e_c is the strain associated with complete compaction and locking, then

$$\dot{z} < c_o \tag{4}$$

The compaction wave is "subsonic" in this case because the secant modulus of the material for the pressure p_o is less than the modulus for stresses below σ_o. Consequently, the compaction front will be preceded by an elastic wave of intensity σ_o propagating at velocity c_o

Conversely, if

$$p_o > p_{cr} \tag{5}$$

then

$$\dot{z} > c_o \tag{6}$$

and the compaction front moves at "supersonic" velocity.

The propagation of the compaction front and the motion of the compacted layer are governed by the equation of conservation of mass and Newton's equation of motion. The medium ahead of the compaction front is either at rest, unstrained, at the initial density ρ_1 or in motion due to the elastic precursor at density ρ_o, corresponding to the stress σ_o and strain e_o. The density of the compacted stratum is ρ_c corresponding to the compaction strain e_c. Conservation of mass requires

$$\rho_c(1-e_c) = \left[\rho_1 + H\left(\rho_o - \rho_1\right)\right]\left[1-He_o\right] \tag{7}$$

where the function H depends on $\dot{z}/c_o$:

$$H\left(\frac{\dot{z}}{c_o}\right) = 0 \quad \text{when} \quad \frac{\dot{z}}{c_o} > 1$$

$$H\left(\frac{\dot{z}}{c_o}\right) = 1 \quad \text{when} \quad \frac{\dot{z}}{c_o} < 1 \tag{8}$$

The motion of the compacted stratum relative to the medium ahead of it is defined by the free boundary displacement u_r, the relative particle velocity $\dot{u}_r$, the depth to the compaction front z_r, and its velocity, $\dot{z}_r$. The equation of motion is:

$$\frac{d}{dt}\left[\rho_c\left(z_r - u_r\right)\dot{u}_r\right] = p\ (t) - \sigma_o H \tag{9}$$

These equations yield two sets of solutions, depending on the initial intensity of the pressure, p_o. In the supersonic case, $p_o > p_{cr}$:

$$z = c_o t\left(\frac{e_o}{e_c}\right)^{1/2}\left[\frac{2\int dt \int p(t)\,dt}{\sigma_o t^2}\right]^{1/2} \tag{10}$$

$$\dot{z} = c_o\left(\frac{e_o}{e_c}\right)^{1/2} \frac{\dfrac{\int p(t)dt}{\sigma_o t}}{\left[\dfrac{2\int dt \int p\ (t)dt}{\sigma_o t^2}\right]^{1/2}} \tag{11}$$

$$\sigma_g = p_{cr}\left(\frac{\dot{z}}{c_o}\right)^2 \tag{12}$$

In the subsonic case, $\sigma_o < P_o < P_{cr}$:

$$z = \frac{1 - e_o}{\left[\frac{e_c}{e_o} - 1\right]^{1/2}} c_o t \left[\frac{2 \int dt \int p(t)\, dt}{\sigma_o t^2} - 1\right]^{1/2} + e_o c_o t \tag{13}$$

$$\dot{z} = \frac{1 - e_o}{\left[\frac{e_c}{e_o} - 1\right]^{1/2}} c_o \frac{\frac{\int p(t)\, dt}{\sigma_o t} - 1}{\left[\frac{2 \int dt \int p(t)\, dt}{\sigma_o t^2} - 1\right]^{1/2}} + e_o c_o \tag{14}$$

$$\sigma_z = \sigma_o \left[1 + \left(\frac{\dot{z}}{c_o} - e_o\right)^2 \frac{\frac{e_c}{e_o} - 1}{(1 - e_o)^2}\right] \tag{15}$$

In EQUATIONS 10 through 15 the position of the compaction front z and its velocity $\dot{z}$ are now given with respect to the original position of the free boundary of the medium and $\sigma_z(z, t)$ is the stress immediately behind the compaction front.

It can be shown that the velocity of an initially supersonic front decays to the sonic velocity c_o at the time when $\sigma(z, t)$ has decayed to P_{cr}. After this time the compaction front does not generally degenerate into an elastic wave, but continues to propagate as a subsonic compaction front preceded by an elastic precursor that moves at a velocity c_o. The compaction front velocity decays monotonically until the time at which $\sigma(z, t)$ decays to the stress σ_o, when compaction ceases and the compacted layer, including the boundary, continues to move at the elastic particle velocity:

$$\dot{u}_o = e_o c_o \tag{16}$$

The sequence of events and formulas describing the various aspects of the stress waves for the less general cases shown in FIGURE 1*a*, c, and *d* can be obtained by inserting the appropriate values of σ_o and e_o in the above general case, FIGURE 1*b*.

Consider next a semi-infinite medium from the second group characterized by the stress-strain diagram shown in FIGURE 2*b*. The same type of blast loading considered above is assumed here. At any time the medium may be separated into two types of regions. The first type includes all regions in which the stress is monotonically increasing with time. In such regions the effective stress-strain curve is the straight line through the origin in FIGURE 2*b*. The medium behaves as an elastic material, and stress waves propagate at the velocity c_1 according to the one dimensional wave equation:

$$\frac{\partial^2 \sigma}{\partial y^2} = \frac{1}{c_1^2} \frac{\partial^2 \sigma}{\partial t^2} \tag{17}$$

where

$$c_1 = \sqrt{\frac{E_1}{\rho}} \tag{18}$$

and E_1 is the modulus of elasticity given by the slope of the initial loading line in FIGURE 2*b*. Since the variation of the density ρ is considered to be small here, this portion of the analysis is limited to small strains.

The second type includes all regions in which the stress is decreasing or is less than the maximum stress previously applied at the particular point in question. In these regions the effective modulus of elasticity E_2 is the slope of the steeper line shown for unloading in FIGURE 2*b*. Stress waves propagate in such regions at the velocity c_2 according to the wave equation:

$$\frac{\partial^2 \sigma}{\partial y^2} = \frac{1}{c_2^2} \frac{\partial^2 \sigma}{\partial t^2} \tag{19}$$

where

$$c_2 = \sqrt{\frac{E_2}{\rho}} \tag{20}$$

When a sudden pressure rise is applied to the boundary of the medium, a stress wave propagates in the positive y direction at the velocity c_1 since the undisturbed material must react to the initial stress rise with the modulus E_1. If the load pressure $p(t)$ decays monotomically after the initial peak pressure p_o, then behind the initial stress front the changes in the boundary pressure propagate at velocity c_2 according to EQUATION 19. The decrements in surface pressure propagating at velocity c_2 into the medium must eventually overtake the initial wave front that moves at velocity c_1. When this occurs, there is a partial reflection of the pressure decrement from the moving initial wave front. The pressure rise across the initial front is decreased by the reflection process and a small positive pressure wave is also propagated toward the surface of the medium at velocity c_2. When the reflected wave reaches the surface of the medium, it is reflected again, and a new wave starts from the boundary.

It is possible to follow the time history of a single pressure decrement by applying the laws of conservation of mass and momentum at each reflection. The mechanics of elastic wave reflections are discussed in Timoshenko.[3] By summing up all contributions of the various reflected waves extant at a particular time, a complete picture of the stress distribution can be determined. The particle velocity distribution can be found by a similar procedure, since the change in velocity due to any pressure change Δp is

$$\Delta \dot{u} = \frac{\Delta p}{\rho c} \tag{21}$$

where c is either c_1 or c_2, depending on whether the wave propagates at a velocity c_1 or c_2. The final results may be expressed in the form

$$\sigma(y, t) = p(t') = p_r(t') + p_r(t'') \tag{22}$$

where $p_r(t)$ is a reflected pressure function defined by

$$p_r(t) = \sum_{n=1}^{\infty} \alpha^n \left(p_o - p(a^n t) \right) \tag{23}$$

and

$$t' = t - \frac{y}{c_2} \tag{24}$$

$$t'' = t + \frac{y}{c_2} \tag{25}$$

$$\alpha = \frac{c_2 - c_1}{c_2 + c_1} \tag{26}$$

The velocity distribution is given by

$$\dot{u}(y, t) = \frac{1}{\rho c_2} \left[P(t') - p_r(t') - p_r(t'') - p_o \right] + \frac{p_o}{\rho c_1} \tag{27}$$

It is of interest to note that in the long-time solution for any case in which the surface pressure $p(t)$ decays to zero in a finite time, the velocity and stress at every point approach zero as the time approaches infinity. This is to be expected in dissipative media in contrast to what happens in an elastic material in which the elastic waves propagate indefinitely.

The medium illustrated in FIGURE 2*a* may be considered as a limiting case of the material shown in FIGURE 2*b* in which the return modulus E_2 approaches infinity. By considering the full range of E_2 from E_1 to infinity, the behavior of materials that range from full elasticity to one with no recovery can be explored. In general, the smaller E_2, the greater the recovery, and the farther a given blast loading will penetrate into the medium. The permanent strains at any point will be smaller, but will be spread through a deeper stratum of the medium.

Summary

The propagation of plane stress waves has been considered in various dissipative media. One category considered is described by a stress-strain

diagram that is parallel to the stress axis beyond a certain critical stress. This is called a locking material and exhibits a permanent strain if loaded above the critical stress. The second category has a linear stress-strain diagram on loading, but is not fully elastic. It exhibits a permanent strain upon unloading from any stress level.

The results have bearing on the behavior of granular soils under blast loading.

References

1. KOLSKY, H. 1953. Stress Waves in Solids. Clarendon. Oxford, England.
2. PRAGER, W. 1957. On ideal locking materials. Trans. Soc. Rheol. 1: 169-175.
3. TIMOSHENKO, S. 1934. Theory of Elasticity. McGraw-Hill. New York, N.Y.

DIVISION OF ANTHROPOLOGY

YOU HAVE NEVER BEEN OLD: A SOCIAL STUDY IN GERIATRICS*

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Assembling social research data through photography has proved to be of great value. One can dispute the spoken or written word, but one cannot dispute visual actualities. Of course, this means one must do most careful research and objectively try to tell the factual truth. At the same time, however, the visual presentation must be a piece of art so that the onlooker is moved by it; it must not be simply the documentation of a given situation. The photographs must tell the story; the text should furnish only explanatory accompaniment.

I have just finished an extensive photographic research study under the auspices of the Mayor's Advisory Committee for the Aged intended to enlighten the public on geriatric problems and to improve existing legislation for the aged in New York, N. Y. I believe I have included a description of most situations in which older people may find themselves in that community today.

Of vital importance to any study in geriatrics is the fact that more and more people now are living longer. In the city of New York there are more than one million people over 60 years of age. Unhappily, our culture tends to discard the older person: old age is thought of as something discreditable, something of which to be ashamed. The realities of aging are beclouded by misunderstanding and prejudice and, as in the case of all prejudices, we are afraid of them.

Since 1900 the population of the United States has doubled, but the number of persons 45 to 64 years of age has tripled; the number of people 65 and older has more than quadrupled. In 1955 there were 14,127,000 people 65 and older, constituting 8.5 per cent of the total population, an increase of 359 per cent since 1900. Between 1950 and 1957, the population of 65 and older increased 21 per cent, while the total population increased 13.3 per cent. In 1950 one in every 12 persons in the country was 65 and older.

In 1956 the economic status of people over 65 was as follows: 60.8 per cent had an income of less than $1,000 a year; 80.8 per cent earned less than $2,000 a year; 18 per cent had no income at all; and only 4.4 per cent had an income of $5,000 and over. In September 1958, 45,648 persons 65 and older in the city of New York received old-age assistance from the Department of Welfare. At the latest census in 1957 the city of New York had 708,984 people 65 and older in a total population of 7,795,471 persons.

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Of the people 65 and older in 1955 in the entire country, 6.2 million received old age and survivors insurance benefits; 2.5 million received no social security benefits, but received public assistance. However, such statistics alone do not tell where and how older people live. I could not get any data in this connection later than 1950. Three and one-tenth per cent of persons older than 65 were in institutions in the United States; of these, 56.4 per cent were in homes for the aged. In mental institutions the percentage of older people is 36.7 per cent (a shockingly large number); 2,097,000 people 65 and older, or 17.1 per cent of the general population, are so-called long-term patients with chronic disabling diseases.

Eighty per cent of older men live in a family unit; 60 per cent live with their wives. Seventy-five per cent of older women live in a family unit, but only 30 per cent live with their husbands. The number of widows is increasing. Ten per cent of older people of both sexes live in rooming houses, hotels, and other such establishments. One in 7 older women are not living in their own homes but with relatives.

I began this study simply by walking through many streets of New York; it is amazing to find that, when one is alert to old age, one encounters so many older faces. Most of the older faces I saw seemed to have unhappy, sad, and dissatisfied expressions. After walking and observing for one month, I began my actual study.

A number of years ago a joint study was conducted by the Cornell University Medical College, the Social Science Research Council, the Department of Health, the Russell Sage Foundation, and the New York Foundation, all in New York, N. Y., to determine what types of community services would be most urgently needed by older citizens of the city. One result of this study was the establishment of an Adult Counseling Service to which people older than 60 could apply for counsel regarding problems dealing with such factors as health, financial assistance, and housing. I chose to use the facilities of an office of the Adult Counseling Service that shared its premises with a Day Center for Older People conducted by the Department of Welfare.

The Adult Counseling Service was remarkable in that it provided applicants with the assistance of a most able staff of counselors, psychologists, nurses, and doctors. I am sorry to report that this vital service was discontinued for lack of funds that the city administration could not or would not appropriate. Many believed that this service constituted an essential program, since one could channel the needs of older people in many constructive directions.

The existing Day Centers for Older People provide recreational activities and companionship from 9 A.M. to 5 P.M. They serve a cheap luncheon, generally for 15 cents. The Day Centers benefit the mental health of their members. However, these centers are closed evenings,

when so many older people lack all recreational resources and suffer from loneliness.

Through the Adult Counseling Service I found five individuals whose lives I investigated. All were members of the same Day Center. These five comprised three widowers and two widows.

One woman received $30 from her social security benefits, with which she paid her rent and utilities and had a remainder of $1 toward all other expenses. She walked great distances. She could not move one of her arms, and visited a chiropractor who lived more than 65 blocks from her home, covering both journeys on foot. The Day Center gave her free luncheons and some bread to take home for herself and her dog. The woman tried to get supplementation from the Welfare Department, but was unable to explain why she had nothing, and failed. Finally, with the help of the Adult Counseling Service, she received her long-awaited old-age assistance from the Welfare Department. Her husband, who had been a taxicab driver, had left her some money, but he was not covered by social security. The woman had been a secretary and therefore received her social security benefit of $30, but of course had used up the small sum the husband had left her.

The other woman, the widow of a butcher, lived on old-age assistance. When I visited her she was in deep depression and despair. Her apartment was poverty-stricken, but by the linen on her bed and her usually well-groomed appearance one could see that she had known better times.

The three men I investigated were as diversified. The first was a retired bricklayer. Because of his age he had not been covered by social security benefits, and he received old-age assistance from the Department of Welfare. His apartment was modest, but cheerful and well-kept. As distinguished from both of the women, who did no creative work but came to the Day Center only for food and companionship and the Adult Counseling Service to discuss their various problems, this man was active as a painter and in woodwork. He played a guitar in the Center's orchestra, and was proficient at the piano. However, he also suffered from loneliness and waited until the Center closed before leaving.

The second man was a retired electrician. He lived on a pension from his union and on social security benefits. He arrived every day at the Center promptly at 9 A.M. and stayed until 5 P.M., when it closed. He did woodwork. He complained that these Centers are closed, not only evenings, but week ends and holidays.

The third man had been a sculptor for the American Museum of Natural History. When he was about 50 years old his department was discontinued because of lack of funds. He applied everywhere for jobs, but was turned down because of his age, although he was a very fine craftsman. Finally, he was able to obtain work at a department store warehouse. Now he is retired. His economic status is quite good, but he lives a very lonely life. He lives with a daughter, who leaves for

work early in the morning and comes home late at night. He works at his sculpture all day by himself, and samples of his work crowd the apartment. When I saw him, he experienced difficulty in talking, since he never has anyone with whom to speak. His wife died three years ago and his friends have either moved away or have died. I asked him if he would like to teach voluntarily at a Day Center near his home. I knew he had refused to become a member of one because he was a professional worker, but he was pleased by this suggestion. He was accepted as an instructor at the Center and was offered a small salary, which elevated his morale greatly. The members of the Center were delighted with his classes, and many who never had been interested in this kind of activity joined his group. However, the Day Center was soon advised to discontinue his services and to get a younger and more modern teacher and, despite the fact that he was an excellent craftsman and a good teacher, his services were terminated.

I visited several homes for the aged, hospitals filled with older patients, and nursing homes. I went to city institutions such as Camp LaGuardia, which is for homeless men, and to the Farm Colony, which is for unattached indigent older people. The Farm Colony earlier was known as a "poor farm." I went to the Men's Shelter for homeless men, where an applicant is admitted only if he possesses less than $2. There are about 25,000 homeless men in the city. I also went to lodging houses, where 60 per cent of the clients are older than 65; most of them are so-called residents without board. These lodging houses are extremely depressing places.

Other older people from the community came to many of the hospitals, homes for the aged, and nursing homes to entertain or to volunteer services; and it was interesting to observe the enormous contrast between these workers and those they visited. These visitors, of the same age group, were young in spirit and full of life. The aged clients in these uncreative, sheltered conditions merely waited to die.

Two programs provide important constructive help for the aged population: the Physical Rehabilitation Center at Goldwater Memorial Hospital and the Geriatric Rehabilitation Center at Kings County Hospital, Brooklyn, a psychiatric rehabilitation center.

The Physical Rehabilitation program at Goldwater Hospital is well rounded and creative, and the patients receive medical care. Here a dedicated group of people work closely together under expert guidance, ensuring highly individualized care. This program includes supervision in all activities of daily living. In addition to physical therapy there is also occupational therapy, speech therapy, a psychologist, social workers, vocational guidance and, finally, a home-care program for the patient after he leaves the hospital.

The Geriatric Rehabilitation Center at Kings County Hospital is of the utmost importance. Even authorities agree that many older people

are placed in mental institutions, not because they belong there, but because there is no other place for them. When one is old, a little peculiar, and poor, it is easy to be committed in a mental institution. In 1958 about 50 per cent of the patients at Manhattan State and Brooklyn State hospitals were older people. For 4000 patients Brooklyn State Hospital had 50 psychiatrists. Older people shared the wards with violent patients in strait jackets. Brooklyn State Hospital at least had a recreation department comprised of enormous auditoriums crowded with both old and young people. The most cheerful element in the picture was a group of student nurses, still young and idealistic. However, Brooklyn State is infinitely preferable to Manhattan State Hospital, where almost nothing was done for older people. I was told: "We cannot do anything for them. We must concentrate on the younger."

It is a well-known fact that older people committed to a mental hospital die soon after admittance. Therefore, a place like the psychiatric Geriatric Rehabilitation Center at Kings County is of extreme importance. It is assumed there that no patient is ever too old to adjust. People in their nineties emotionally so malajusted on admission that it was found necessary to bind them in their chairs have been improved sufficiently to be able to return to the community. One woman admitted was not only antisocial in bearing, but also extremely unkempt and dirty, with disheveled hair. She had collected such quantities of paper, rags, and other trash that her home was a fire hazard. She desired neither to talk nor to sit near anyone; she felt cheated and exploited. After approximately one month at the Center she changed and became neater and cleaner. She still collected some trash, but finally she began to take part in social activities and became friendly.

It is unfortunate that this institution is extremely understaffed and has far too few trained people. Most of the workers are nurses'aides. There were a few trained nurses and two psychiatric social workers, one of whom instilled fear in patients. This functionary always asked new arrivals if they were afraid, if they feared the future, the present, or what might happen to them. The director was the only trained psychiatrist, and he was not always available. The most constructive work here was done by the associated Day Center. Although this program had many shortcomings that could have been adjusted easily, most patients showed marked improvement. The program of the Center, despite its inadequacies, points a way for the future.

Some housing projects have set aside a few apartments for older people, both couples and individuals. The building of housing units for older people exclusively has been suggested, but it has proved unwise to segregate older people from the general stream of life. The Department of Welfare has a program called Boarding Home, a kind of foster-care program for older people. This program creates for an older lonely person a family atmosphere and a sense of belonging. Today it

is generally agreed by social workers that homes for the aged have outlived their usefulness as such and that they must gradually evolve into nursing homes and hospitals.

The Peabody Home is a Protestant home for "gentlewomen." This home has no waiting list because it has a nonresident club from the members of which residents are drawn as necessary.

An outstanding feature of the Mary Manning Walsh Home, a Catholic institution, is that there is a minimum of restrictions on movement and on the kind of people admitted as regards race, creed, and religious affiliation.

The Home for Aged and Infirm Hebrews provides home-care, home-making, and outside-living programs. I visited a couple receiving home care who had been married for 63 years. Both were in their eighties and both were chronically ill. If they had been separated because of their physical condition, they probably would have not survived, especially since they were devoted to each other. The Home kept them together in their own surroundings and attended by a homemaker and a visiting nurse. The outside-living program furnished clients with small apartments or rooms near the home in which they received all the services of the institution.

We now come to the important issue of employment. Advertisers and employers wish us to believe that "ripe old age" begins at about 35. However, the New York State Department of Labor helped me locate firms in which it had found positions for older workers. A man interviewed there was a designer about 50, for whom the State Employment office tried to find a position. This designer had become unemployed, and only odd jobs could be found for him. Some employers condidered an older worker a person about 35 or 40; others reserved this category for persons 60 or even 70 years old. Two industrial concerns, I found, did engage people in their sixties and seventies, both men and women, asserting that the older worker is more reliable, more conscientious, more adaptable, and less inclined to absenteeism.

What does the labor movement do for older people? One of the first labor unions to recognize the needs of older people was District 65 of the Retail, Wholesale and Department Store Union, AFL-CIO. This group was the first to initiate a retirement and pension plan including full protection for health and medical care paid for by the union instead of by the retired workers. All beneficiaries remained active members, having a voice and many duties in the union.

The impressive activity of many older people emphasizes the fact that it is never too late to learn. I have known people as old as one hundred years who learned to read and write. Some in their nineties learned to speak English. People in their eighties and nineties take courses in philosophy at the New School for Social Research.

We now come to the most important point in this study. Is it necessary to be afraid, or sad, or sick, when one becomes old? Must one become lonely, unhappy, destitute, maladjusted, or insecure? Of course, our social laws should be improved. Medicine will increasingly postpone and prevent the onset of the aggravations of old age.

For a study of adjusted older people, I selected nine individuals of varying backgrounds; these subjects were rich and poor, famous and unknown, and from seventy to ninety years old. All taught me the same thing: that mental health is all-important. If a person is a vital, creative, and mentally healthy human being, he will remain so as he becomes older.

Examples of this thesis include Eleanor Roosevelt; Stanley Isaacs, the minority leader of New York City Council; Bela Schick, the discoverer of the Schick test and still a very active pediatrician; Alvin Johnson, president emeritus of the New School for Social Research; and William DuBois, educator and author. All these people are famous; we know they are all active, and we think of them as exceptions. However, there is Anne Nichols, a retired seamstress, who uses all of her spare time as a Senior Citizen Volunteer; she brings much love and happiness to patients at Bird S.. Coler Hospital and many other places. Pat Kelly, who worked for 25 years for the National Broadcasting Company and was known as the dean of the announcers, trained such people as Dave Garroway and Ben Grauer. He was forced to retire when he reached 65 and he told me: "Couldn't stand it. No aim, no future. This birthday, this one day changes all." Now he teaches every day at the biggest television school in the city. Douglas Daniels took his Junior High School examination when he was about 80 and is now in high school. He hopes, if he lives, to go to college. One of the most charming women I have ever met is Eva Bernstein, a painter, weaver, linoleum printer, and sculptor, a most creative woman. She began abstract painting when she was 79 years old, after her husband had died. When I met her she was 90. I asked her if she was ever lonely and she replied very beautifully: "I am never lonely; I have so much here. I read a lot and think a lot. I see my family and friends constantly. They feel, when they come to visit me, that I do too much and tire myself, but I don't. I know how much I can do." Then she added: "Sometimes it is painfully quiet and sometimes it is lovingly quiet."

One can only admire so admirable an adjustment.

DIVISION OF MYCOLOGY

I. FACTORS INFLUENCING THE UPTAKE AND TOXICITY OF FUNGICIDES*

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If toxicants are to control fungus diseases through effects on the germination of conidia, they should be taken up readily in quantities sufficient to have an irreversible preventive action on germination. Experiments have shown that many toxicants in use for this purpose are, indeed, taken up very rapidly by conidia. [5, 8-10] Exposure periods of only a few minutes may be sufficient to produce the desired effect. Even during such short periods, large quantities on a spore-weight basis may be taken up, and it is apparent that the successful use of a given toxicant depends upon the ease with which spores will accumulate the poison as well as on its innate toxicity.

Experiments were carried out with conidia of *Neurospora sitophila* (Mont.) Shear and Dodge; *Monilinia fructicola* (Wint.) Honey; *Aspergillus niger* van Tiegh; *Alternaria oleracea* (Milbraith); *Glomerella cingulata* (St.) Sp. and von S.; *Venturia pyrina* Aderh.; *Rhizopus nigricans* Ehr.; and yeast cells, *Saccharomyces cerevisiae* Hansen. Toxicants used have included 2-heptadecyl-2-imidazoline, 2,3-dichloro-1,4-naphthoquinone and silver, mercury, cerium, cadmium, zinc, and copper.

Numerous experiments on the uptake of toxicants in solution by spores suspended in aqueous media have shown that the quantity taken up is controlled primarily by the amount of toxicant available per unit weight of spores rather than by the concentration of the applied solution. Thus, LD_{50} values based on the concentration of the external solution are of little help in measuring innate toxicity. The toxic effects produced are determined by the quantities of toxicant that have been taken up by the spores by the time they are removed from the treating solution. There are exceptions to this in instances in which the toxicants are fungistatic rather than fungicidal. Examples of this are known among the metals (copper, zinc, and cadmium, for example[5]) and also among organic toxicants.

Removal by spores from the ambient solutions of large quantities of toxicant, sometimes representing a ten thousand fold accumulation compared to the concentration of the applied solution, naturally brings up the question as to whether the toxicants enter the spores or are merely

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adsorbed on the surface. This cannot be answered unequivocally until more information is available. Work must be done to accumulate ions against a concentration gradient but, if the ions or compounds are precipitated by receptor sites or dissolved by lipids or other cell contents, this is no longer the case. If receptor sites in or on spores are readily available to toxicants, then rapid uptake can be explained on this basis. Some toxicants are taken up readily by spores previously treated so as to make them incapable of germination.[9] This shows that receptor sites are also readily available in such spores, as well as in viable spores. Of course, spores that have been rendered incapable of germination, depending upon the method used, may still have many metabolic processes in functioning condition, at least for a time.

The spores used in these tests were always harvested in water and were washed once or twice more before being subjected to the toxicants. In work with spores labeled with P^{32} or S^{35} it was found that 15 to 20 per cent of the labeled compounds are released into the ambient solution by this washing procedure.[6] Determination of the total dry weight released gave the same results.[4] Most of the material is lost on the first suspension in water and only a little more by a second suspension. The cell contents remaining are held more firmly, but certain treatments can bring about a further release of some cell contents without necessarily impairing the germination capacity. The materials are removed in such large quantities that it is not believed that the contents of the washings consist only of exudates that may be on the spore surfaces when they are harvested. Fungal conidia may have an area more readily accessible to the external environment than the remainder of the cell, similar to what has been called free space or outer space in some other plant cells studied.[2]

The results obtained in studies on toxicant uptake and on release of cell contents both with or without the presence of toxicants and on distribution of toxicants in various cell fractions after sonic disintegration[11] all lead to the conclusion that conidia are fairly permeable to various materials. It does not seem to be as difficult for various substances to penetrate spores as is generally believed. Certain sensitive receptor sites possibly are located on or near the surface. Rothstein and his co-workers[12] have studied yeast cells extensively and believe that a considerable portion of the interaction between these cells and various added chemicals takes place at the cell surface. Similarly, Lowry *et al.*[3] suggest that, when dormant ascospores of *Neurospora crassa* are subjected to various cations, these are adsorbed at the surface and do not gain access to sensitive receptor sites until germination occurs. Much earlier, Goldsworthy and Greene[1] reported that the toxic action of the copper in Bordeaux mixture to spores of *M. fructicola* does not take place until germination begins. Different conclusions reached by various groups of workers result in part because

of investigations with different organisms and toxicants and in part because of different interpretations of essentially similar data.

Since the quantity of toxicant taken up by spores is the determining factor in effects on germination, as determined by dosage-response curves, it is important to know what factors affect such uptake. Experiments have shown that alterations of permeability of the membranes may be involved. It was found that pretreatment with silver markedly increased the uptake of mercury even when the quantity of silver used was so low as to have little effect on germination.[10] Recent experiments have shown that silver also increases the uptake of some, but not all, other toxicants studied.

The effect of other ions on the uptake and effectiveness of toxicants is of theoretical as well as practical interest. Sprays as applied for the control of fungus diseases contain other biocides and extraneous agents. Any interactions among these, either in the spray solution or in affecting uptake of the desired toxicant, are therefore important.

Experiments have shown that interferences in uptake among ions are much more pronounced when the ions are presented to the spores simultaneously than when they are used in consecutive treatments. Ions that would be expected to compete for the same receptor sites naturally would be expected to show interference. However, it has been found that unrelated ions also may affect each other. This may be due to phenomena that take place at the spore membrane.

An example has been found in which ions, nontoxic in themselves, enhance toxicity without increasing the uptake of the toxicant. Iodide increases the toxicity of mercury tenfold or more, according to the quantity of mercury required to inactivate the spores.[7] The iodide can be supplied to the spores after the excess mercury in the treating solution has been removed. On the other hand iodide, which forms a very insoluble compound with silver, entirely prevents the uptake of this ion and thereby any toxicity to fungus spores.[5] Some interferences between ions may thus be due to reactions taking place in the ambient solution. Ions such as cyanide, which interferes strongly with the uptake of mercury, may act through complex formation in the solution.[7]

Some of the results obtained suggest an effect on permeability. Interesting interactions have been noted between cerium and silver. If spores of *N. sitophila* are pretreated with cerium, there is no effect on the subsequent uptake of silver. However, if cerium is present simultaneously with the silver, then quantities as low as 0.1 by weight of the silver present will retard uptake. If the addition of cerium is delayed until a few minutes after the silver has been added, uptake of silver is not retarded. With yeast cells under comparable conditions, cerium had no such effect on the uptake of silver, although yeast cells have a much greater affinity for cerium than do spores of *N. sitophila*.

On the other hand, silver increased the uptake of cerium by spores of *N. sitophila*. Presumably this is the result of the effect of silver on permeability. Silver did not increase cerium uptake by yeast. It seems that the receptor sites for cerium are much more readily accessible in yeast cells than in spores of *N. sitophila*.

Of special interest are ions that increase the effectiveness of other ions or compounds or promote the uptake of the toxicant. Recently it has been found that treatment with acetate increases the uptake of cerium. Acetate is actively metabolized by fungus spores and, apparently, this results in greater permeability of the spores to cerium.

In many of these responses of ion interference and in the toxicity studies, marked differences were found between spores of different species. Low toxicity is not necessarily associated with lowered uptake by the species in question. More basic information on the physiology of spores of the important species would aid greatly in interpreting results of toxicity studies.

References

1. GOLDSWORTHY, M. C. & E. L. GREENE. 1936. Availability of the copper of Bordeaux mixture residues and its absorption by the conidia of *Sclerotinia fructicola*. J. Agr. Research. **52**: 517-533.
2. KRAMER, P. J. 1957. Outer space in plants. Some possible implications of the concept. Science. **125**: 633-635.
3. LOWRY, R. J., A. S. SUSSMAN & B. VON BÖVENTER. 1957. Physiology of the cell surface of *Neurospora* ascospores. III. Distinction between the absorptive and entrance phases of cation uptake. Mycologia. **49**: 609-622.
4. MCCALLAN, S. E. A. 1951. Mechanisms of toxicity with special reference to fungicides. Proc. 2nd Intern. Plant Protection Conf. Fernhurst Research Stat. England. : 77-95.
5. MILLER, L. P. & S. E. A. MCCALLAN. 1957. Toxic action of metal ions to fungus spores. J. Agr. Food Chem. **5**: 116-122.
6. MILLER, L. P. & S. E. A. MCCALLAN. 1957. Movement of ions and compounds into and out of fungus spores. Science. **126**: 1233.
7. MILLER, L. P. & S. E. A. MCCALLAN. 1957. Mechanism of action studies of the effect of fungitoxicants in destroying fungus conidia. Proc. 4th Intern. Plant Protection Congr. Hamburg, Germany. In press.
8. MILLER, L. P., S. E. A. MCCALLAN & R. M. WEED. 1953. Rate of uptake and toxic dose on a spore weight basis of various fungicides. Contribs. Boyce Thompson Inst. **17**: 173-195.
9. MILLER, L. P., S. E. A. MCCALLAN & R. M. WEED. 1953. Accumulation of 2-heptadecyl-2-imidazoline, silver, and cerium by fungus spores in mixed and consecutive treatments. Contribs. Boyce Thompson Inst. **17**: 283-298.
10. MILLER, L. P., S. E. A. MCCALLAN & R. M. WEED. 1954. The use of radioisotopes in studying the affinity of various toxicants for fungus spores. Proc. 2nd Radioisotope Conf. Oxford, **1**: Med. & Physiol. Applications. :381-390.
11. OWENS, R. G. & L. P. MILLER. 1957. Intracellular distribution of metal ions and organic fungicides in fungus spores. Contribs. Boyce Thompson Inst. **19**: 177-188.
12. ROTHSTEIN, A. & A. D. HAYES. 1956. The relationship of the cell surface to metabolism. XIII. The cation-binding properties of the yeast cell surface. Arch. Biochem. Biophys. **63**: 87-99.

II. MORPHOLOGY OF *NEUROSPORA CRASSA**

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It was early observed by Beadle[1] that a mutant of *Neurospora crassa* requiring myoinositol, when cultured on suboptimal amounts of the vitamin, grew with an altered colonial morphology. Tatum *et al.*[2] induced similar aberrations in wild-type *N. crassa* with L-sorbose and surface-active agents. Genetic colonial mutants lacking detectable nutritional markers but having a characteristic, specific, single-locus mediated morphology have been described by Barratt and Garnjobst.[3]

Several efforts have been made to determine the biochemical bases for these morphologic variations. Fuller and Tatum[4] found that m-inositol was present in *N. crassa* mycelia as a phospholipid complex, and postulated a structural function for the compound. The inositolless mutant, when grown in an inositol-deficient medium, was found to contain a characteristic low level of inositol as compared with mycelia cultured on optimal amounts of m-inositol. However, further biochemical studies indicate that colonial and normal morphology may exist with no difference in total inositol content of the mycelia. Several fungi studied by Barnett and Lilly[5] were found to be inhibited in the absorption or utilization of sugars by the hexose, L-sorbose. Based on temperature studies, these workers suggested an effect of L-sorbose on enzyme activity. Seki,[7] using cell-free extracts of *N. crassa*, was unable to demonstrate an effect of L-sorbose on hexokinase, glucose dehydrogenase, or glutathione reductase. However, Lardy *et al.*[6] showed an inhibition of hexokinase by L-sorbose-1-phosphate in isolated enzyme systems of animal origin.

A light microscopic comparison of the wild-type cells with the several types of colonial forms reveals variations in hyphal size and shape and in branching pattern. In an effort to understand better the morphology of *N. crassa* and possible abnormalities at the fine structure level, an electron microscope study has been undertaken.

Materials and Methods

Lyophilized cultures were grown on glycerol-sucrose complete agar slants for 3 days at 30° C. Conidia were transferred to 20 ml. of liquid media in 125 ml. Erlenmeyer flasks and grown at 25° C. with slow shaking for 15 to 20 hours. Wild-type (SY7A) was cultured on 1 per cent sucrose and 0.1 per cent sucrose-0.9 per cent sorbose minimal media. The inositolless strain (37401-152-1-7a) was grown with colonial

*This paper, illustrated with slides, was the second of two papers presented at a meeting of the Division on February 27, 1959.

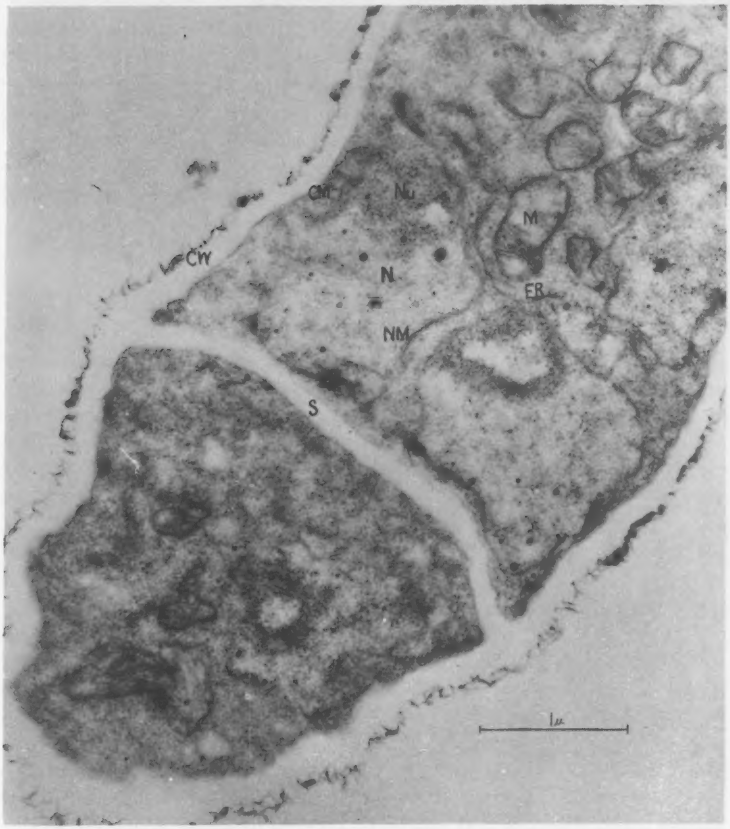

FIGURE 1. *Neurospora crassa* wild-type hypha cultured on sucrose minimal medium. Legend: *CW*, cell wall; *S*, septum; *CM*, cell membrane; *N*, nucleus; *NM*, nuclear membrane; *Nu*, nucleolus; *M*, mitochondrion; *ER*, endoplasmic reticulum.

morphology on 1 per cent sucrose minimal medium containing 0.25 gamma/ml. m-inositol or with normal morphology on the same medium containing 10 times the quantity of m-inositol. A genetic colonial mutant, B110, was cultured in 1 per cent sucrose minimal medium.

Mycelia were prepared for electron microscopy by the standard procedure of Palade,[8] except that uranyl nitrate was added to the methacrylate-embedding medium to prevent cell rupture.[9] Sections with an estimated thickness of 50 mμ were cut on the Porter-Blum microtome and examined in the RCA electron microscope.

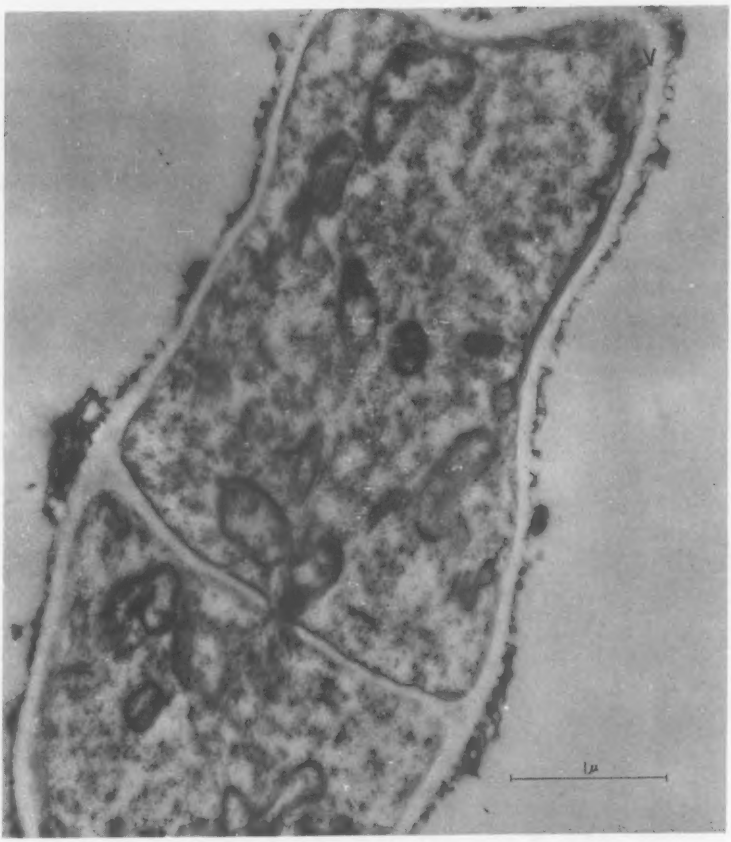

FIGURE 2. *Neurospora crassa* wild-type hypha cultured on sucrose minimal medium. The fibriform network on the outermost surface of the cell wall is more extensive opposite the septum. Cytoplasmic streaming indicates active cell growth. Particles of 100 Å diameter occur throughout the cytoplasm. A system of membranes parallels the cell membrane and encloses ringlike vesicles *V*. The location of the membranes suggests that they are involved in cell wall synthesis.

Results

Morphology of wild-type cells. The wild-type *N. crassa* cell cultured on sucrose media has a diameter of 3 to 4 μ and may reach a number of microns in length. It is enclosed by a chitinous[10] polysaccharide wall about 0.1 μ thick. Little internal structure is discernible within a large part of the wall after osmium fixation. However, in early experiments

where cell rupture occurred, the cell wall of mutant B110 separated into at least three distinct layers. Light microscopic observations of hyphae before fixation reveal more dense regions at the outermost wall surface opposite sites of cross-wall formation. Electron images of these thickenings indicate that they are due to increased amounts of an electron-dense fibriform network that coats the cell surface. In the case of the colonial mutant B110, the excrescences at the surface also appear at short distances from the wall, suggesting a sloughing-off process. The sorbose-grown cells apparently have a weakened cell wall, as evidenced by the pronounced tendency of these cells to undergo methacrylate explosion. They also have a strikingly increased development of the fibriform meshwork over that of sucrose-grown cells.

In growing hyphae, formation of cross walls or septa occurs by an invagination of the cell wall, followed by fusion of the infolded parallel wall surfaces. As new wall material is laid down, the diameter of the cytoplasmic connection between the cells diminishes to a size of 0.20 to 0.25 μ. The process of constriction stops here, rendering the hypha coenocytic. Both nuclei and cytoplasm have been observed to stream through the opening. As the hypha ages or is damaged, the pore is closed by a plug composed of 2 cylindrical bodies. These are 0.06 μ in length and are separated by a disc 0.02 μ thick. Intense osmium staining suggests a lipoid nature for the plug.

Immediately within the cell wall lies a sinuate plasma membrane that often appears as two distinct membranes. Innumerable infoldings in the cell membrane result in a greatly increased surface area. The invaginations sometimes are continuous with membrane profiles that extend into the cytoplasm, forming channels open at the membrane surface. Ringlike vesicles appear between the cell wall and membrane, enclosed in pockets formed by membrane invagination. Such structures have been described for the Basidiomycete *Polystictus versicolor*.[11]

Parallel and adjacent to the cell membrane is a well-developed system of smooth membranes. This system appears in profile as channels several microns in length, and is reminiscent of the endoplasmic reticulum of higher organisms.[12] The location of these membrane-limited structures close to and paralleling the plasma membrane suggests that they are involved in the synthesis of cell wall material.

The granular cytoplasm is intensely basophilic and contains dense, regular particles of a diameter of about 100 Å. The staining reaction is removed on treatment with ribonuclease.[13] It is probable that the particulate component of the cytoplasm is ribonucleoprotein as seen in animal, plant, yeast, and bacterial cells.[14]

In addition to the agranular membranes, the cytoplasm contains a reticulum that appears as vesicles and channels in section. These internal membranes have an associated particulate component that resembles the free particles of the cytoplasm in size and density.

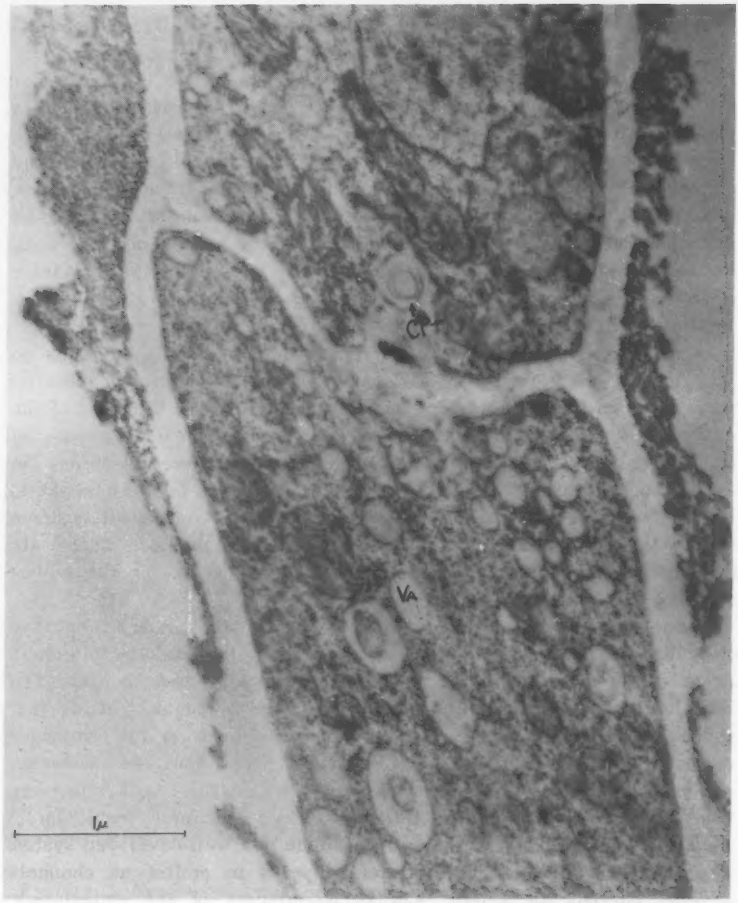

FIGURE 3. *Neurospora crassa* wild-type hypha grown on sorbose-sucrose minimal medium. The meshwork at the external wall surface is extensive. Membrane-bound vacuoles *Va* and concentric membrane profiles *CP* occur in the cytoplasm.

The numerous mitochondria are of the classic type described by Palade[15] and seen previously by Tsuda.[16] Although they are usually convoluted, their general shape is that of a rod with dimensions about 0.2 to 0.3 × 1 to 2 μ. Variations in both size and shape occur. The organelle is enclosed by an outer continuous membrane. Within this is a second membrane that infolds to form a series of internal parallel ridges, the cristae. The cristae usually lie perpendicular to the long

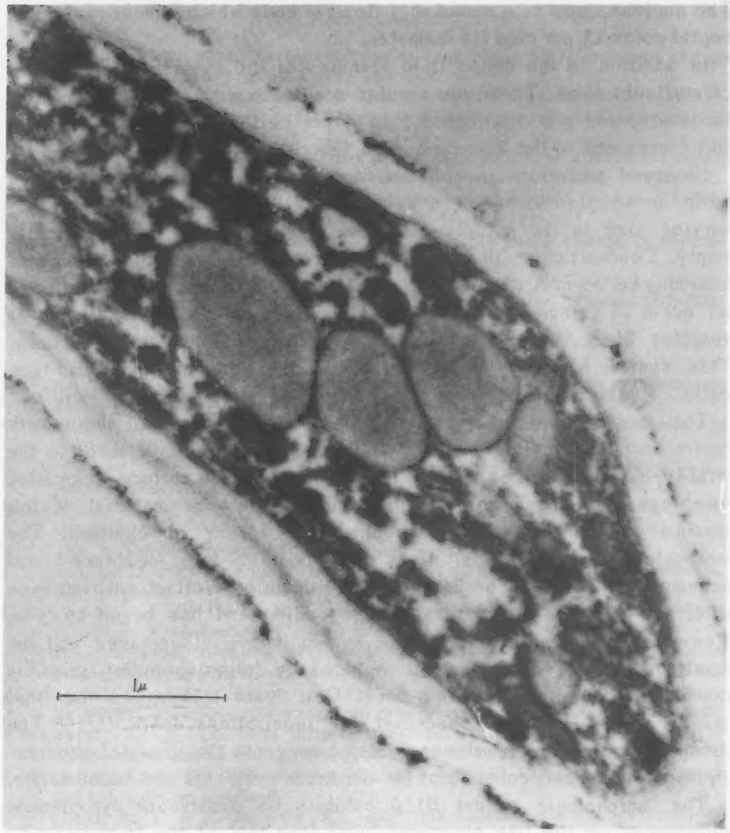

FIGURE 4. Hypha of inositolless mutant of *Neurospora crassa* grown with colonial morphology on sucrose minimal medium containing 0.25 gamma/ml. m-inositol. The cytoplasm contains large, membrane-bound accumulation bodies.

axis of the mitochondrion, but may also appear parallel, as in the case of yeast.[17] Bifurcated mitochondria suggest that they arise from pre-existing ones.

Several oval, Feulgen-positive bodies 1.5 to 2.0 μ in diameter, the nuclei, occur in each cell. In the electron microscope they appear as regions enclosed by 2 apposed membranes. Pores of 400 to 700 Å width occur at intervals in the double membrane envelope.[18] The nucleolus is a region of granularity of high electron density that is usually closely associated with or attached to the nuclear membrane.

The nucleus itself is a remarkably flexible body which squeezes through septal pores 15 per cent its diameter.

In addition to the dense lipid granules of the cytoplasm, hexagonal crystalloids exist. These are regular structures with sides 0.2 to 0.3 μ in length, and are distributed 1 to 2 per cell in thin sections. They may correspond to the Woronin bodies described by Buller.[19]

Observed variations in colonial forms. The sorbose-grown wild-type cells, in addition to having a weakened cell wall, contain vacuoles of varying size in the cytoplasm. These usually appear to be optically empty. Concentric profiles of membranes enclosing particulate material also may be seen. A system of agranular vesicles about 0.25 μ in diameter occur in groups and enclose smaller vesicles of 350 Å. The larger vesicles break down, releasing the smaller ones into the cytoplasm. This system has been observed only in the sorbose-grown wild-type cells. Similar systems have been described by Sotelo and Porter.[20]

The inositolless strain cultured on optimal amounts of the growth factor is morphologically comparable on a fine structural level to the wild-type cells grown on sucrose media. However, the surface-associated membranes are less well developed, and islets of material of low osmium affinity, possibly carbohydrate, appear in clusters. The morphologically grown inositolless strain contains large membrane-bound accumulation bodies. The mitochondria remain as distinct entities even after the cell is full of these dense bodies and has begun to lyse. However, the organized membrane systems have disappeared and the small particulate component is replaced by larger granules, possibly condensations of the smaller ones. Cell lysis follows as the final stage in what has been described as "inositolless death."[21-23] The disappearance of the membrane systems suggests that inositol phospholipid is a necessary constituent for membrane synthesis and maintenance.

The morphologic mutant B110 exhibits no observable cytoplasmic differences on the fine structural level from that of the sucrose-grown wild-type cells. Other genetic colonial forms are being studied.

Summary

The fine structure of *N. crassa* hyphae, including the cell wall, membrane, nuclei, mitochondria, endoplasmic reticulum, and cytoplasmic inclusions is described. Some differences observed among the various colonial forms are noted.

Acknowledgments

I express appreciation to E. L. Tatum, under whose direction this work is being done. I also thank K. R. Porter and G. E. Palade for the use of their facilities and valuable suggestions.

References

1. BEADLE, G. W. 1944. An inositolless mutant strain of *Neurospora* and its use in bioassays. J. Biol. Chem. **166**: 683.
2. TATUM, E. L., R. W. BARRATT & V. M. CUTTER. 1949. Chemical induction of colonial paramorphs in *Neurospora* and *Syncephalastrum*. Science. **109**: 509.
3. BARRATT, R. W. & L. GARNJOBST. 1949. Genetics of a colonial micro-conidiating mutant strain of *Neurospora crassa*. Genetics. **34**: 351.
4. FULLER, R. C. & E. L. TATUM. 1956. Inositol-phospholipid in *Neurospora* and its relationship to morphology. Am. J. Botany. **43**: 361.
5. BARNETT, H. L. & V. G. LILLY. 1951. The inhibitory effects of sorbose on fungi. Science. **114**: 439.
6. LARDY, H. A., V. D. WIEBELHAUS & K. M. MANN. 1950. The mechanism by which glyceraldehyde inhibits glycolysis. J. Biol. Chem. **187**: 325.
7. SEKI, L. Unpublished observations.
8. PALADE, G. E. 1952. A study of fixation for electron microscopy. J. Exptl. Med. **95**: 285.
9. WARD, R. T. 1958. Prevention of polymerization damage in methacrylate embedding media. J. Histochem. Cytochem. **6**: 398.
10. BLUMENTHAL, H. J. & S. ROSEMAN. 1957. Quantitative estimation of chitin in fungi. J. Bacteriol. **74**: 222.
11. GIRBARDT, M. 1958. Über die Substruktur von *Polystictus versicolor L.* Arch. Mikrobiol. **28**: 255.
12. PALADE, G. E. 1956. The endoplasmic reticulum. J. Biophys. Biochem. Cytol. **2**: 85.
13. TSUDA, S. Personal communication.
14. MICROSOMAL PARTICLES AND PROTEIN SYNTHESIS. 1958. R. B. Roberts, Ed. Pergamon Press. New York, N. Y.
15. PALADE, G. E. 1953. An electron microscope study of mitochondrial structure. J. Histochem. Cytochem. **1**: 188.
16. TSUDA, S. 1955. Electron microscopical studies of ultra-thin sections in *Aspergillus*, *Penicillium*, and *Neurospora*. Indian Phytopathol. **8**: 83.
17. AGAR, H. D. & H. C. DOUGLAS. 1957. Studies on the cytological structure of yeast: electron microscopy of thin sections. J. Bacteriol. **73**: 365.
18. WATSON, M. L. 1955. The nuclear envelope. Its structure and relation to cytoplasmic membranes. J. Biophys. Biochem. Cytol. **1**: 257.
19. BULLER, A. H. R. 1933. Researches on Fungi. V: 127. Longmans, Green and Co. London, England.
20. SOTELO, R. J. & K. R. PORTER. 1959. An electron microscope study of the rat ovum. J. Biophys. Biochem. Cytol. In press.
21. STEVENS, C. M. & A. MYLROIE. 1953. Inhibition effects of back-mutation tests with mutants of *Neurospora*. Nature. **171**: 179.
22. STRAUSS, B. S. 1958. Cell death and 'unbalanced growth' in *Neurospora*. J. Gen. Microbiol. **18**: 658.
23. LESTER, H. E. & S. R. GROSS. 1959. An efficient method for the selection of auxotrophic mutants of *Neurospora*. Science. **129**: 572.

NEW MEMBERS

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